TOPOGRAPHIC MAPS *and* SKETCH MAPPING

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PREFACE

THE demand for instruction in map reading and sketch mapping, brought about by the Great War, has led to the development of a course on this subject in many of our colleges and technical schools which have assisted in preparing men for the various officers' training camps. Outside of the purely military field our universities have in the past found it necessary to develop a course of this character for students in Geology and Physiography who are required to make extensive use of topographic maps. In recent years the development of the automobile and the camping habit has led to a more extensive use of maps by the general public, and a large number of people have "discovered" our own United States Geological Survey Maps, but are still unable to understand them completely and to make the fullest possible use of them.

It will doubtless be necessary in the future for many educational institutions to continue instruction in this subject for students taking reserve officers' and other military training courses in connection with their regular college work. Furthermore it seems probable that in many of our institutions the demand and necessity for such a course will lead to its inclusion as a regular academic study, given perhaps as a part of the instruction in Geology or Geography, or as a separate course under Civil Engineering. It is with this idea in view that this volume has been prepared.

A large number of educated people have never learned to use topographic maps because it has been the general opinion that considerable mathematical knowledge was necessary. This is far from true. During the past few years it has been necessary to give instruction in this subject to a great number

of men who never went beyond "plain" geometry, who passed this point many years ago and claimed to have forgotten all they ever knew of mathematics. They have picked up the subject quickly and are generally the most interested students and do the best work. This has been particularly true of work in sketch mapping and in several cases men have stated that they intended securing the simple Army sketching outfit and using it on summer outing and camping trips. Indeed there is no reason why work of this kind could not be made part of the instruction in the summer camps for boys. Interesting applications could easily be worked out and it would doubtless stimulate interest in the practical mathematical problems.

The author had the pleasure of cooperating with Dr. Charles P. Berkey, of the Department of Geology of Columbia University in giving the course on "War Topography," originated by Dr. Berkey for the Students' Army Training Corps. The notes prepared for this course have formed the basis for the present work. The author takes pleasure in acknowledging his indebtedness to Mr. F. K. Morris, of the same department, with whom he cooperated in giving a similar course, for many ideas of value. Mr. Morris has also contributed a Descriptive List of the Principal Topographic Maps of the World, which will be found in the appendix. This is believed to be the most complete list of this kind which has ever been published. A number of the questions following the first sections are based on the mimeographed notes prepared for infantry and field artillery candidates at Fort Sheridan, Major Cromwell Stacey, Senior Instructor.

J. K. F.

New York City,
August, 1919.

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INTRODUCTION

A MAP is a conventional picture of a portion of the earth's surface as seen from directly above, showing more or less completely the various features of the country represented. Thus a land map may show only the boundaries of a certain piece of property and would consist simply of a series of lines forming a closed figure with the lengths and directions determined by the surveyor—in short a conventional outline of the property in question. On the other hand, a complete "topographic" map, such as would be used in planning a landscape design for a park or estate, for example, would show every detail of the property—houses, roads, streams, and even, in some cases, individual trees as well as the relief, or ups and downs of the land surface which form its hills and valleys. Between these two extremes are all sorts and kinds of maps used for various purposes.

Maps may be divided into two main classes—flat maps and maps showing relief. The former class embraces most of the maps with which we are familiar. They may show the principal features such as cities, towns, railroads, roads, rivers, streams, etc., but make no attempt to show the mountains, hills and valleys. In some maps the main mountain ranges are shown by a form of shading and, as the scale or size of the map in relation to the ground represented becomes larger, it is possible to give with increasing accuracy the relief, and to show more and more of the details of the country. Thus it would not be possible to show on a map of the United States, say twelve inches long, much more than the boundaries of the States, the main rivers and large mountain ranges, and to indicate by small circles their principal cities If this same size, twelve inches, is used to represent a few acres of country it is practicable to show nearly all the details mentioned for the landscape map above with the relief so clearly shown that small

inequalities in the land surface of a few feet in height would be accurately indicated.

Practically all the nations of the world have either made or are now making topographic maps of their land possessions. These maps are generally published in sections and show a portion of the land surface drawn so that one inch on the map represents about a mile of land. In Europe the making of these maps has been largely inspired by military considerations. In the United States the main object has been to furnish maps suitable for the economic development of the country, the study of its geological structure and resources and the planning of engineering projects. For this reason our maps, published by the U. S. Geological Survey, are not good maps for military purposes, but they do show very clearly the relief which is of great importance in engineering work Such European maps as the French and German show every detail of military importance, but the relief has been shown largely by line shading which is easy to understand but not very definite or accurate. Greater care in showing relief was thought to be unnecessary and these maps were well suited to the tactics of open warfare which prevailed up to 1914. Modern warfare, however, tends to settle down to intensive action along almost fixed lines with a great deal of engineering construction in the form of trenches, mines, etc., and any advance must be preceded not only by the accumulation of vast quantities of stores and construction equipment behind the lines, but also by the complete planning of the engineering features of the construction to be done as the troops advance. For this work neither the size nor method of showing relief in vogue in Europe before the war was suited, so we have seen, since the war began, the issue of new, larger and more detailed maps of much of France in which the accurate American contour method of showing relief is used.

The ability to understand a topographic map and make use of the data shown in answering various questions in regard to the country represented is required of every officer and even the non-commissioned officers in the United States Army. The study of maps with this end in view is generally termed "Map Reading" and its importance in warfare will

be readily appreciated when we think that every tactical movement, varying in size from the movement of an entire army down to a trench raid, is not only planned on a map but orders are issued with reference to a certain map or maps. Map reading may be divided into two parts. *A*. A study of the method of representing features on a map and *B*. How to make use of the map to obtain certain information.

Map making is primarily the field of the engineer, and in modern warfare they are usually prepared by a special engineering force trained and equipped for this purpose and assisted by aeroplane observers. Accurate up-to-date maps were found to be so important on the western front that specialists were developed in all the branches of the work from the purely engineering features of surveying to the interpretation of aerial photographs and the printing of the final map. New maps of active sections of the front were printed right behind the lines with field equipment and issued almost daily. In many cases large size maps were not available and officers had to make their own sketch maps to serve until better maps could be made and issued. This was particularly true in the recent activities on the Mexican border and in the campaigns in the Far East where good maps had never been made. It has thus come about that officers in our army must not only be able to use maps, but to make them, and for this purpose the Army Sketch Case has been developed. A similar simple outfit is used by many geologists for field work in new country which has never been fully mapped Such work, while not highly accurate, furnishes valuable information for various purposes, and is covered by the subject of Sketch Mapping given in Part II. It is part of the required training for all infantry officers. Artillery officers have to go much deeper into the subject and, while sketch mapping will furnish an excellent start, it will be found advisable to follow it up with a thorough course in surveying and the use of the surveyor's instruments.

The subject of Landscape or Panoramic Sketching discussed in Part III is primarily of military importance. Simple sketching of this kind, however, is a very interesting pastime and will be found of value in illustrating geological and other reports and as an aid in visualizing topographic maps.

TOPOGRAPHIC MAPS AND SKETCH MAPPING

PART I

MAP READING

CHAPTER I

WHAT A TOPOGRAPHIC MAP SHOWS

ART. 1. TOPOGRAPHIC MAPS

As has already been pointed out a **topographic map** is a conventionalized picture of a section of the earth's surface as seen from directly above. In fact a good topographic map shows the surface features of the country represented so perfectly that it is possible to make an exact model of the country, called a relief map, from it. Topographic maps have important uses both for civil and military purposes. Every road, railroad, canal, dam or bridge is first planned and laid out on a topographic map. On these maps the engineer studies out his problems in construction, determines the best location for his railroad, the best location and spans of his bridges, even the location of his construction plant and camp. The geologist also uses topographic maps in studying physiography and working out the relations between surface and underground structure. Indeed it is easily possible to form a very clear idea of the age of the land forms and the character of the soil, behavior of streams and sub-surface waters and the underground structure of any section of country from a topo-

graphic map. This subject, which is properly a part of the study of Geology and Physiography, is known as Map Interpretation.*

For those who enjoy the open and wish to study and know the country traversed in auto trips or on camping excursions a topographic map is the best possible guide.

In military work the necessity of complete, up-to-date military maps has been noted. These **military maps** are simply topographic maps to which additional information of a military nature has been added. They guide the operation of parties in the field, give positive information about the country in advance, and serve not only as a basis for planning all military movements, but also for directing artillery fire. In connection with the latter it should be noted that in modern warfare the target is seldom visible to the gunner and the direction and range which are required in aiming the gun are very often taken directly from a topographic map.

There are five **essential features** or divisions of a topographic map.

(a) *The Title*, showing the location of the country represented—when the map was made—who made it, etc.

(b) *The Conventional Signs*, by means of which the various features, such as streams, towns, roads, etc., are represented.

(c) *The Pointer or Arrow*, by means of which the map may be properly oriented and directions determined.

(d) *The Scale*, which shows the relation between lengths, or distances, as they appear on the map and the actual distances on the ground.

(e) *The Relief*, or the method of showing the shape, slope, and height of the hills and valleys

* See "The Interpretation of Topographic Maps" by Salisbury and Atwood Prof Paper No 60 U S G S also "Military Geology and Topography," Edited by Prof. Gregory Yale Press.

Art. 2. Title and Marginal Information

In former times it was the custom to make the title of the map a very elaborate affair which occupied quite a portion of the sheet and was highly decorated. With the adoption of rectangular sections for maps this practice could no longer be followed and the name, characteristics and history of the map, which make up the title, was, of necessity, placed around the margin of the map.

Extensive topographic maps are made, as has already been noted, in sheets varying usually from 15 to 20 inches in height to 20 to 30 inches in width. When these sheets are bounded by meridians and parallels of latitude they are only approximately rectangular, due to the fact that they represent a portion of the curved surface of the earth which is shown on a plane. Most systems of projection,* or methods adopted to show on a plane surface the meridians or parallels of the globe, require that the meridians at the top of the map be closer together than at the bottom for maps of the northern hemisphere and the reverse for the southern. Such maps cannot, therefore, be fitted exactly edge to edge so as to lie perfectly flat, but may be made to do so by leaving a small space between the vertical edges. In other cases the edges of the maps are not based on latitude and longitude lines but are perfectly rectangular. The meridians and parallels of latitude when shown will, therefore, not be parallel to the edges of such maps. The International Maps† and our own U. S. G. S. maps are examples of the former system and the English, French and German of the latter. In connection with longitude it should be noted that the origin is seldom stated. The meridians on English and American maps are based on Greenwich as the origin while the French use Paris, Italian Rome, and German Ferro

Each of the sheets of a given country is given a name or number, or both, which is printed on the margin of the sheet. The name given is either that of the principal town or topo-

* See "A Little Book on Map Projection" by Mary Adams London 1914 George Philip & Son

† See appendix for description of principal government topographic maps

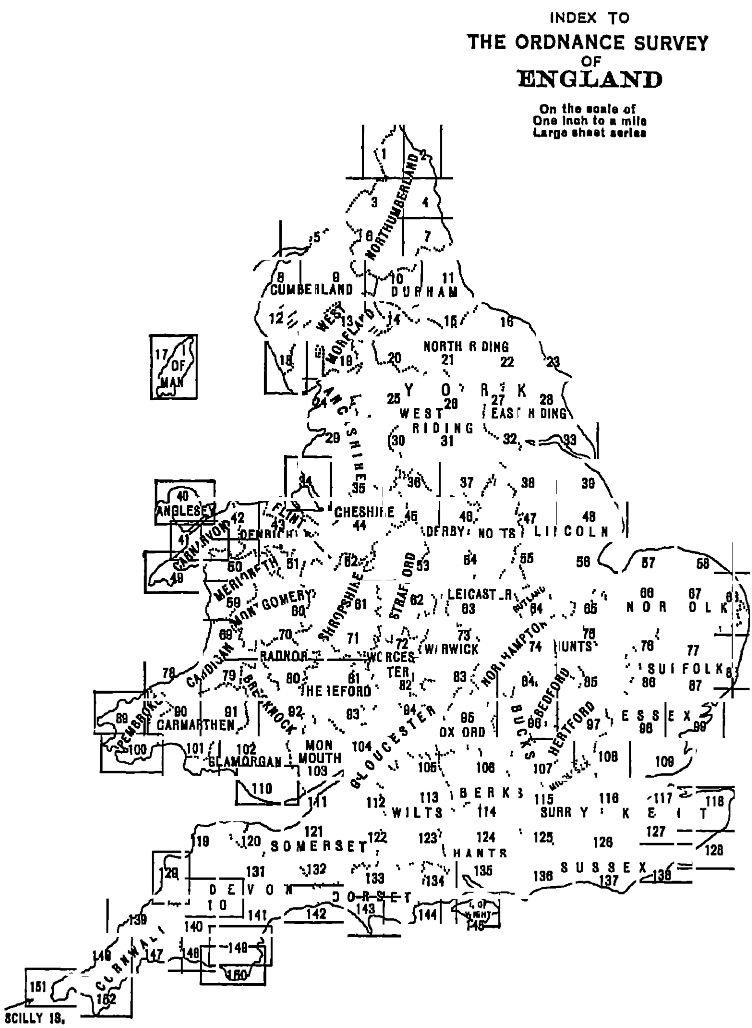
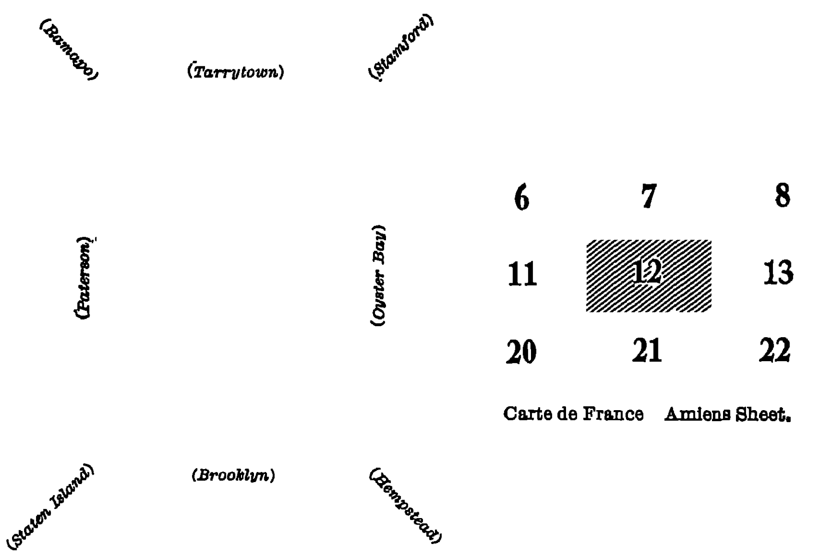


FIG 1 —Index Map Ordnance Survey of Great Britain

graphic feature on the sheet. It is obviously necessary, in order to select the sheet covering any particular section, to have some system of naming or numbering these individual sheets, of which there are 273 in the "Carte de France," 697 in the old "one inch" series of the Ordnance Survey of the British Isles and several thousand for the U. S. G. S. maps. For this purpose **Index Maps** are issued showing a large section of the country with its main features, and the outlines of the sheets with their names, numbers or both. See



U S G S. Harlem Quadrangle

FIG 2.—Methods of Indicating Adjoining Sheets.

Fig. 1, which shows the index sheet for some of the English Ordnance Maps.

It is also the custom to give on most maps the names or numbers of adjoining sheets. This is done either by printing the names of these sheets on the margin of the map, as in the U S G S. maps, or by a small index map on the margin showing the numbers of adjoining sheets The latter method is followed on French and English maps. See Fig. 2.

The term "characteristics" was used above to cover the marginal information relating to the scale of the map, the north point or direction, data concerning the elevations

and relief and conventional signs. These features are discussed in succeeding articles and will not be taken up here except to note that this information really forms part of the title of the map.

The **history** of the map is also noted more or less completely. This may cover 1, the name and officers of the organization issuing the map, 2, the names of the topographers in charge of the parties which made the surveys for the map, with the sections surveyed by each party indicated by a small key map, 3, the date of issue of the original edition and subsequent editions of the map, and 4, a note of the date of revision. The first of these history notes is valuable in telling us the origin of the map and from whom additional sheets may be obtained. The third is important in referring to certain maps, as considerable changes are frequently made in the manner of printing, etc , of different editions. "Provisional Editions" are also frequently issued which may be either compiled from the best available information, as is the case with a number of the English International Maps, or may simply indicate a cheaper edition produced by a more rapid and inferior process, as has been done with the Carte de France. The date of issue or revision is obviously of great importance in using the map as topographic features change from time to time when new or better roads are built and other public works carried on This feature is particularly important on large scale maps which show a large amount of detail that changes quite rapidly. The importance of constant revision of the maps used in detailed military operations such as were involved in the battle-fields of France in the Great War has been noted. The issue of up-to-date maps almost daily was made possible by the use of photographs taken by observers in aeroplanes.

In addition to the above data it is the custom of some countries to print the price of each sheet on the margin. Our own U. S. G. S. maps have printed in gray ink on the back, an outline of the work of the survey, forms in which the maps are issued, and how to obtain them, as well as a quite complete table of conventional signs.

ART. 3. CONVENTIONAL SIGNS

The large number of natural and artificial features that go to make up the topography of any section of the earth's surface requires a corresponding variety of signs or symbols for their representation on maps. This necessitates not only the use of symbols of various forms and shapes, but also different colors, and even the thickness of lines and the style of lettering have their significance. In fact it is necessary in many cases to leave out a number of these features on maps of a small scale, such as most of the government maps, where one inch on the map usually represents about a mile on the ground. On any map we must seek a balance between clearness, legibility and the amount of detail that can be shown, bearing in mind the use to which the map is to be put. The U. S. G. S. maps are a good example of clearness and legibility and the elimination of a great deal of detail, while the German maps are filled up with such an amazing number of signs that a magnifying glass is necessary in using them and the main topographic features are so blended in and covered up that they are not prominent and obvious. The former maps, as has been mentioned before, are not primarily for military purposes Only a few sheets have been printed showing vegetation* and on all sheets there are only two symbols for roads. This road feature* is probably their weakest point and renders them almost useless in picking automobile routes. On the other hand European maps make a great point of roads and are more widely used than our maps by tourists.

It should also be remembered that the cost of a map involves not only the cost of the original work but also the cost of keeping it up to date by printing revised editions which changes in the topographic features make necessary. Large scale maps with many signs showing great detail are not only expensive to make but show features that change

* See for example the Canaseraga and New Berlin Quadrangles, New York The new military maps of the U S (see War Dept Bulletin No 64) to be made in cooperation with the U S G S contain this feature as well as a distinction between the first class and secondary roads A few of these sheets, identical in other respects with the U S G S map, are already issued

so frequently that it is necessary to revise them almost yearly in order to keep them correct and up to date.

It is obvious, therefore, that the number, size and character of conventional signs will vary with the scale of the map and the object for which it is made. It is customary to print a special "characteristic sheet" giving the various conventional signs, lettering, etc., and on each map sheet the principal signs used on the sheet. It is desirable, however, to have a fairly accurate knowledge of these signs so that constant reference to the marginal key, or "legend" as it is sometimes called, is unnecessary. Furthermore some maps such as the Carte de France and the German maps give no such legend and a key is absolutely necessary in using them. The principal signs used on American, English, and French maps will be described briefly.*

The feature of relief is sometimes included as a conventional sign but is here treated separately.

United States Geological Survey. The principal signs used are shown in Fig. 3. A large number of additional signs have been approved by the U. S. Geographic Board for use by all map making departments of the government including the military. These are printed in full in the "Topographic Instructions of the U. S. Geological Survey," where they occupy some nineteen pages, and also in War Department Document No. 418. With the exception of those shown herewith, which are the signs that are common on the U. S. G. S. sheets, these signs are not very extensively used.

The signs used cover land boundaries, survey points, roads, buildings, water features, etc, and are printed in black and blue. Only two signs for roads are shown on the U S. G. S. maps as noted above. A sign for metaled roads (identical with that of the French National Road, see Fig 5) has been adopted and it is hoped will be used in the near future as a better designation of the kind of road represented is much to be desired on these maps. Triangulation stations and bench marks are permanent points, usually marked on the ground by tablets, and used in making the survey for the map.

* For complete comparison of practically all government signs see "Military Topography." Hagadorn.

CONVENTIONAL SIGNS

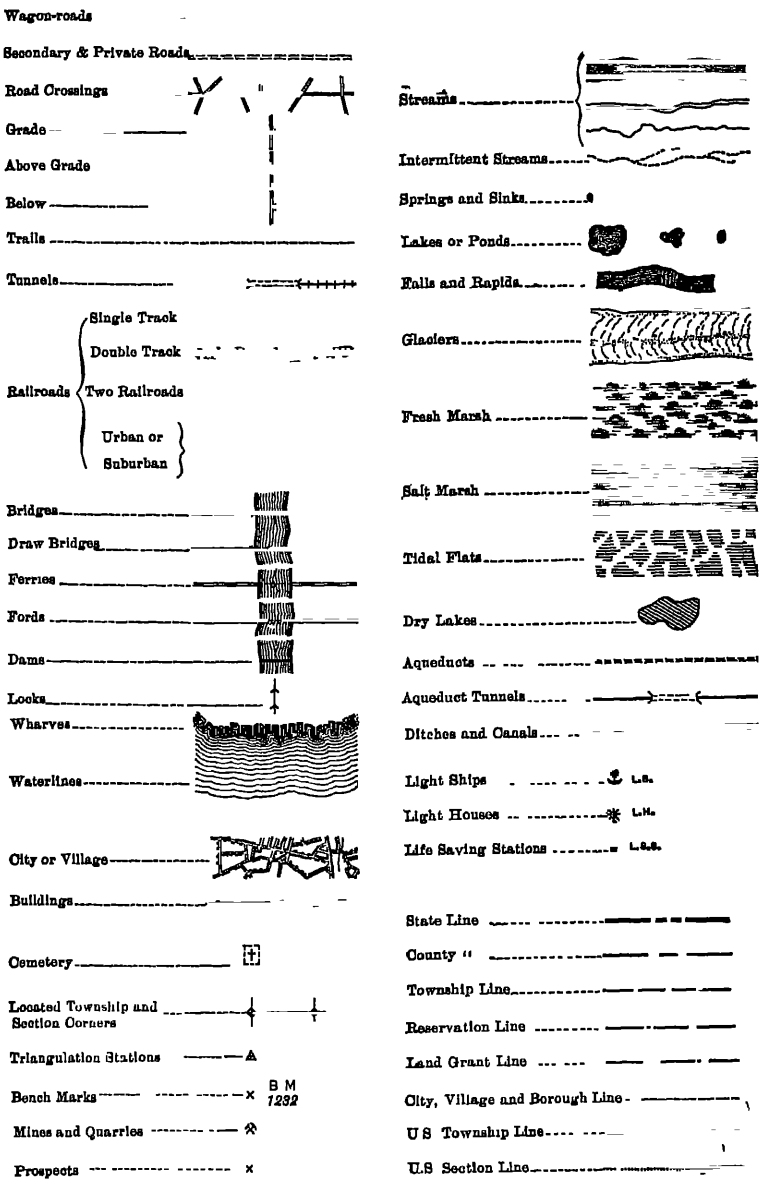


FIG 3—Principal Conventional Signs of U. S G S.

The height of the latter above sea level is indicated by the figures. The blue color used for "hydrography," or water features, makes them easily distinguishable.

Note in connection with these maps that special forms of lettering are used for civil divisions (state, county, town, cities, etc.,) for hydrographic features and for relief.

QUESTIONS

Refer to Fig. 13, p. 28 Note that in using this map the brown relief lines are not referred to They are explained later

1. Are the Western Maryland and the Baltimore & Ohio single- or double-track roads?
2. How many bridges and tunnels are there on the Baltimore & Ohio within the limits of this map?
3. Are there any means for transferring trains from one of these lines to the other? Where?
4. Are there any locks or tunnels on the C. & O. Canal?
5. What is the character of the road between Hansrote and Magnolia?
6. What is the dotted line running from Magnolia up the map?
7. Assuming five people per house what is the population of Hansrote?
8. Is there a railroad station at Hansrote? At Baird?
9. In what way does the road cross the river between Orleans and Little Orleans?
10. What is the small symbol about ¾ inch from the left edge and 1¼ inches above the bottom of the map?

Large-scale Maps. As an example of large-scale maps the Hunterstown sheet of the Gettysburg-Antietam War Game Map will be found in the pocket in the back cover. This map was made at the Army Service Schools, Fort Leavenworth, Kansas, and is based on the work of the U S G S. Note that points on the map are described by marginal letters and numbers. Thus Hunterstown is described as D-5, meaning that it is on the level of the marginal letters D on the sides and about on a vertical through the numbers 5 at the top and bottom. Note the conventional signs for this map which are shown in Fig. 48. The signs for out buildings cannot always be distinguished from houses as they frequently do not print clearly. Points where large streams are less than 5 or 6 feet deep are indicated by dots. Note also that the points of the toothed symbols used for cuts and fills always point down the slope. Vegetation that is insufficient

for concealing troops is shown by the cultivated field sign while corn is specially noted. These features of the map would of course vary from year to year. The following questions refer to this sheet:

QUESTIONS

1 What is represented by the rectangular groups of circles one and one-half inches to the left of Guernsey? (A-8)
2. Is there underbrush in the woods below and to the right of Texas? (C-8.)
3 Is there underbrush in the woods one and one-half inches to the right of Goldenville? (C-8)
4. What vegetation is there in the field below and to the left of Goldenville? Below and to the right?
5 What vegetation is there in the field left blank below Heidlersburg? (A-5)
6. Can you hide on top of the hill numbered 664 near Hamilton? **(D-8.)** On hill 592 near Good Intent S. H ? (C-7)
7 Where is there a ford across the Conewago?
8. Is Opossum Creek more or less than 15 feet wide?
9. Is there a cut or a fill on the railroad at Guernsey station? (A-8.) One inch below Guernsey station?
10. What is the straight saw-toothed sign leading up and to the left from Hershey Mill? (B-6)

Art 4. Conventional Signs—(*Continued*)

Ordnance Survey of British Isles. Fig. 4 shows the characteristic sheet for the maps of this survey in most common use—namely, those drawn so that one inch on the map represents a mile on the ground. Four editions of these maps have been published—one in black, one in color and two other editions, or variations, in one of which the relief is shown by hill shading and in the other by the layer system, both of which methods are described later.

Roads are divided into four classes and one feature peculiar to these maps is that roads with fences on the sides are shown by continuous lines, while unfenced roads are shown by dotted lines. In the colored edition first- and second-class roads are filled in solid in an orange red.

The sign used for railroads is also peculiar to British Ordnance maps. That for single lines is identical with the narrow gage railroad sign of the new French maps. We also

note on these maps that "cuts and fills" are shown. Cuttings are places on roads or railroads where it has been necessary to excavate a trench through a hill, and fills are embank-

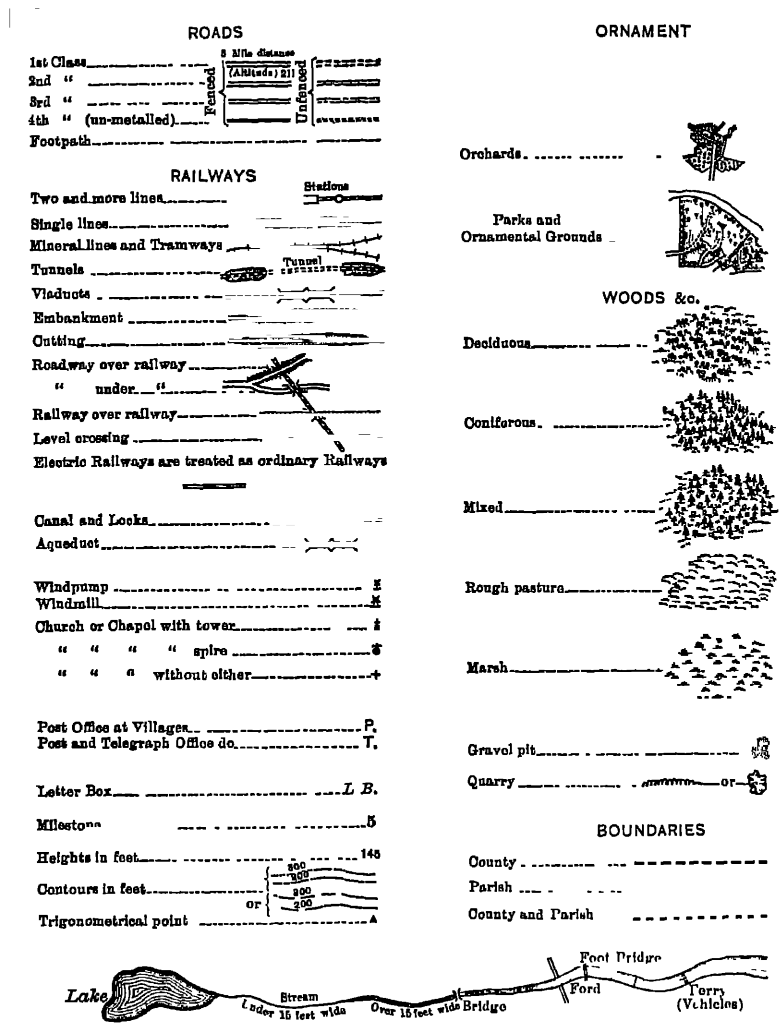


Fig 4.—Characteristic Sheet for English Ordnance Survey.

ments built to carry lines over valleys and other depressions. These features are important from the military standpoint as they would furnish cover for troops and in engineering work they show whether it is possible for a road to cross a

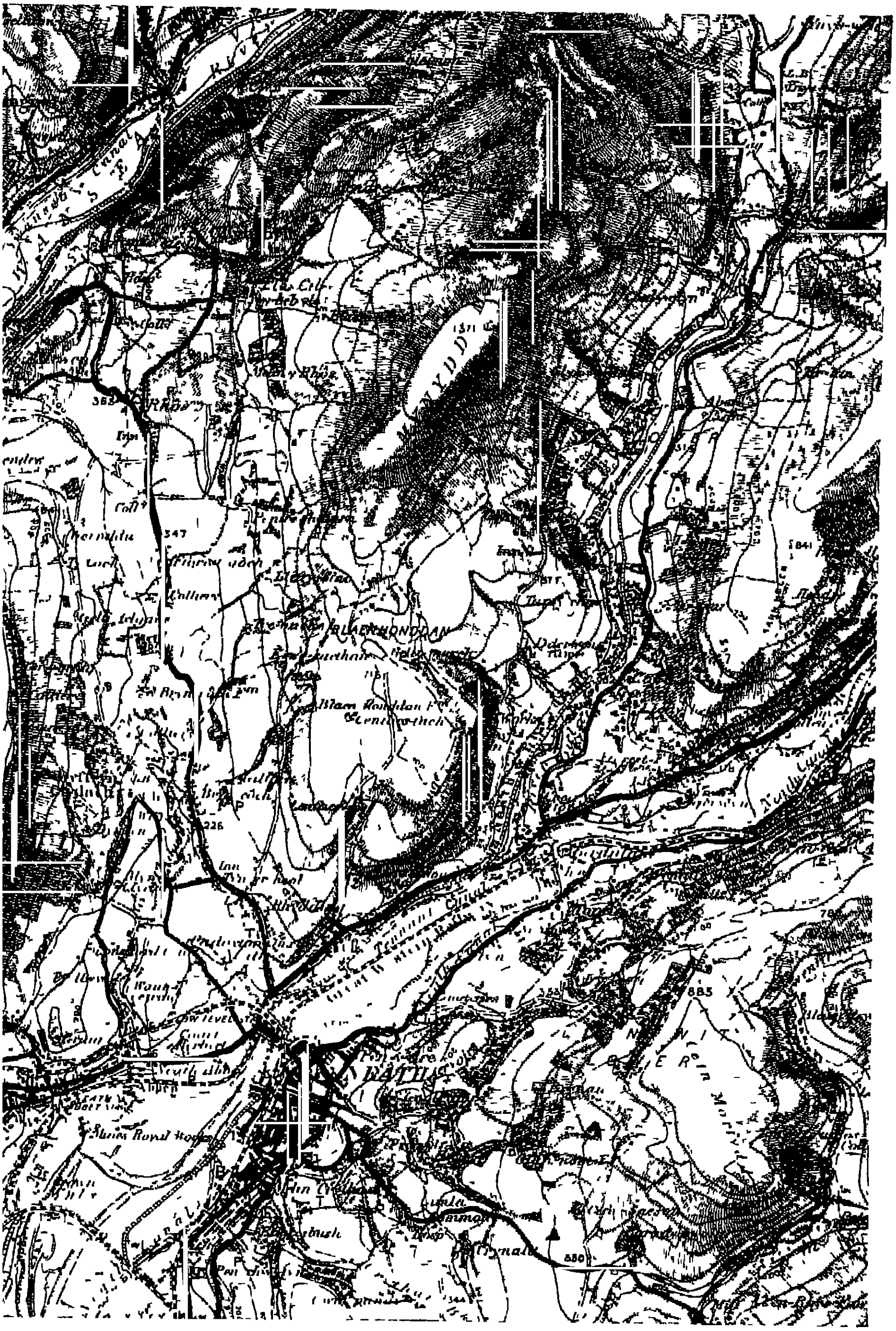


Fig. 5.—Portion of the Swansea and Merthyr Tydfil Sheet ...

railroad, for example, either above grade (overhead crossing) or below grade instead of using the objectionable grade (or

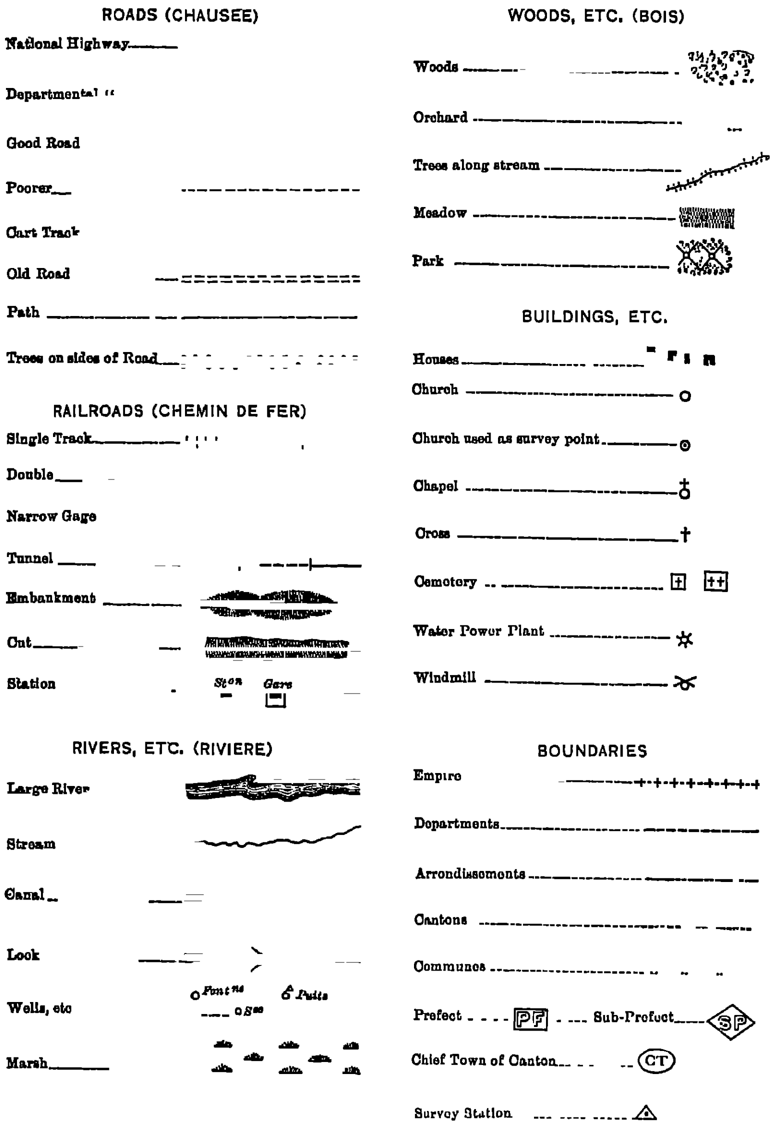


Fig. 6 —Principal Conventional Signs of the Carte de France

level) crossing. The use of a special sign for these features is common on European maps and in the detailed maps

used on the Western Front in the Great War special attention was given to showing all cuttings and the depth was also indicated.

Water features are shown on the colored edition in blue, streams less than 15 feet wide being shown by single lines and wider streams by a double line with water lining.

Woods are shown by small tree symbols, the area covered being also tinted green on the colored maps. Tree signs symmetrically arranged indicate orchards. Parks are shown by a stippling of black dots. Fences are shown only when outlining the area of woods, parks or estates. Buildings are shown by solid black rectangular shapes, a post office being marked by a P, telegraph by T, and a letter box L. B.

One interesting point is the use of a certain style of lettering for antiquities, such as Roman and Druidical remains. Egyptian capitals are used for Roman, old English for remains not Roman, but prior to 1066 (Battle of Hastings) and German text for the period 1066 to 1688.

QUESTIONS

Refer to Fig. 5

NOTE—In using this map neglect all the shading and curved lines which represent the hill forms These will be explained later

1. Is there any difference between the road going toward the upper left-hand corner (Swansea Valley) from Neath and that going toward the upper right-hand corner?
2. Do these roads have fences on each side or are they unfenced?
3. How many kinds of railways are shown on this map?
4. What are the faint horizontal markings slightly above the center of the map?
5. What do the dozen peculiar marks two and a half inches below the top of the map and one inch in from the right edge represent?
6. What do the two letters L and B near road one-half inch in from upper right-hand corner represent?
7. What is the character of the church at Neath?
8. Point out a road that is unfenced?
9. Point out a road fenced on one side only?
10. What is represented by the fine black dots covering the area to the right of Neath near the reservoirs?

La Carte de France de l'État Major. This is the principal map of France, conceived by Napoleon and has been the

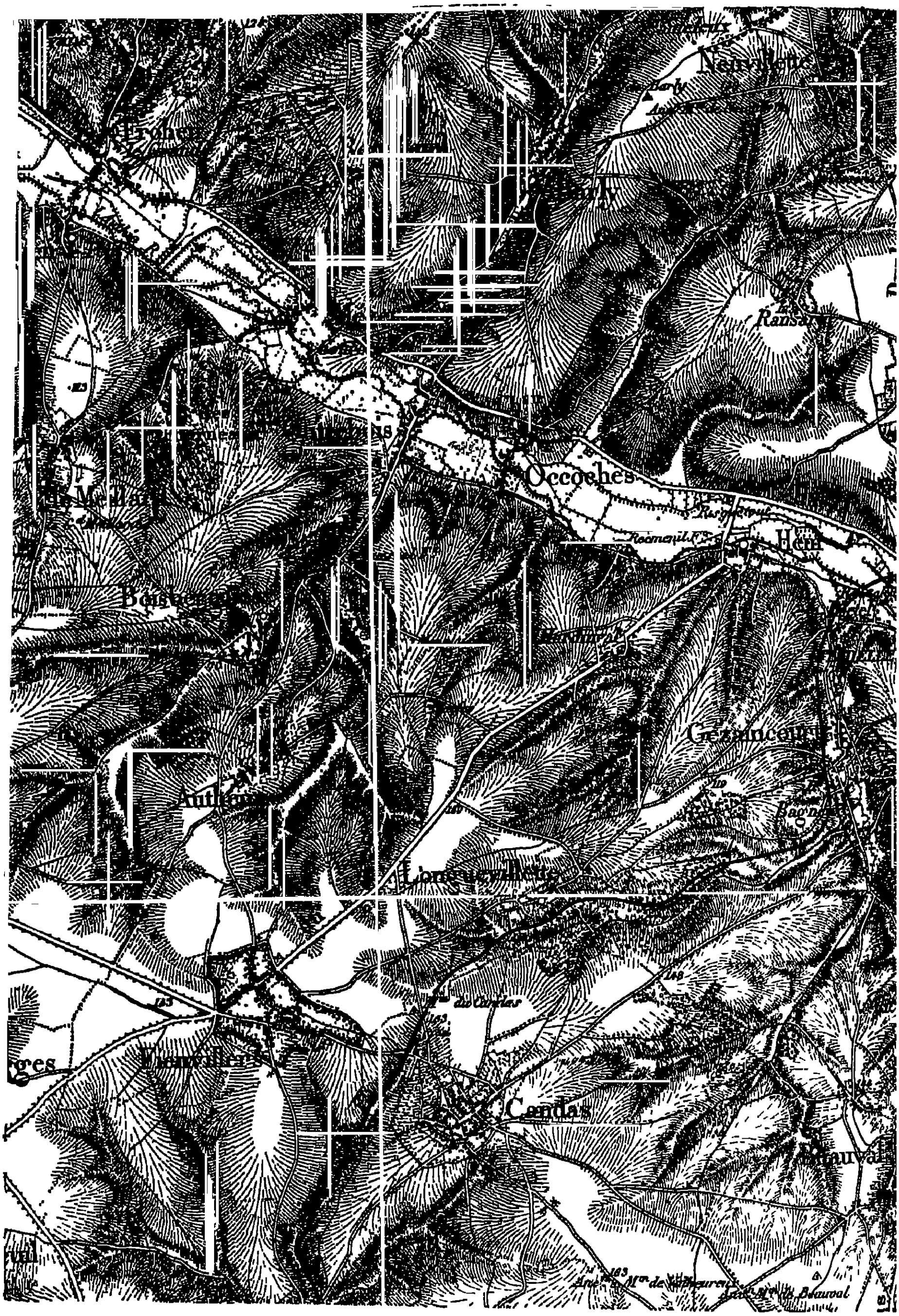


FIG. 7 —Portion of the Amiens Sheet (No 12) of the Carte de France d l'Etat

inspiration for many European surveys.* Fig. 7 shows a typical section of this map which is printed in one color only, and Fig. 6 gives the principal topographic signs.

Note that railways having two or more tracks are shown by solid lines of varying thickness depending on the number of tracks. Single-track lines are shown by the same symbol which is used on the U. S. G. S. maps. Care must be taken not to confuse cart tracks with narrow-gage railroads. The latter will usually run out from main lines. Note also that a new feature is introduced on the road signs which have small dots on either side representing trees. Do not confuse these dots with those used to indicate a commune boundary, which also frequently runs along a road. There is practically no difference between the "Route Nationale," which is maintained by the State in excellent condition, and the "Route Departmentale," which is differentiated from the former solely for administrative purposes.

Windmills are shown by a special sign which is simpler than the English, and churches which have been used as survey points in making the map are also specially indicated.

The various boundary lines are carefully indicated and the principal town of each canton is indicated by an oval enclosing the letters C. T., while the Bureau de Prefect, Bureau de Sub-Prefect, etc., are also shown in a similar way. The forest signs are much like the English.

A few abbreviations are used on the English maps but French maps contain many, the meaning not always being plain. Chau = Château (mansions), Chnee = Cheminée (factory chimney), Min = Moulin (mill), etc.†

QUESTIONS

Refer to Fig 7.

NOTE The black shading lines representing hills should be neglected. They are explained in Art 5

1. Is there any difference between the two roads leading to Fienvillers (lower left) from the left?
2. What are the three peculiar signs about one-half inch below Candas (lower center)?

* See Appendix

† See "Aids to the Use of Maps employed by English, French, Belgian, and German Armies" By Thos Drew London Jarold & Sons.

3. Is there a cemetery at Longuevillette?
4. Are there any industries served by water power along the Authie River?
5. What is represented by the dots surrounding Candas?
6. What is the small triangular mark just across the railroad from the number "153" above Candas?
7. What do the abbreviations stand for just above and below this number? (See 6.)
8. What is the character of the road from Brisbergues (left center) to Fienvillers?

Art. 5 Relief

Three methods, hachures, contours and shading, have been used on maps either singly or in combination to show the relief, or variations in the height of the earth's surface, which form hills and valleys. The method adopted to show the relief must indicate clearly three things: 1, the shape and size of the hills; 2, the slope, and 3, the height of the ground. While the contour system does all three of these things with the highest accuracy of any method yet devised it has the disadvantage of being harder to understand than the hachure or shading systems. It is more difficult to form a mental picture of what the ground represented looks like, that is, it is more difficult to visualize the relief from a contour map than from these other forms. Accuracy is so important in these days, however, that contour maps are gradually coming into wider use and various aids, such as shading, colors, etc., are sometimes used to assist in visualizing the relief.

The **hachure method** doubtless originated from the outlines and shading which were used to show hills on the birds-eye-view-maps of the 16th and 17th Centuries * As finally developed they consist of short shade lines running directly down the slopes of the hills, that is, they show the direction in which water would flow down the hill The shape of the hill is thus quite apparent from these lines (see Fig 7) The slope of the hill is indicated by the thickness and spacing of the individual hachure lines. A steep slope is indicated by heavily inked lines very close together Darkly shaded areas therefore indicate steep slopes, while lightly shaded portions are gentle slopes, and level areas are left without any shading

* See Hagadorn, "Military Topography," for reproductions of some of these maps

The exact height of the ground is only shown at important points on hachure maps. This is done by means of "spot levels" or "spot heights" scattered over the map and giving the height, or elevation, of certain points. Thus, referring to Fig. 7, which is a hachure map, the height of Fienvillers (lower left) is 153 meters above sea level as indicated by the number "153" or spot height, just to the left of the town. In connection with the Great War these spot heights were frequently used to describe hills that had no other names. Thus "103 Meter Hill" simply meant a hill having no name but shown with a spot height of 103 on the map. In naming hills in this way it is of course necessary to state also the locality, as there may be a number of hills of this height. The hachure method is very common in European maps, being the method used for the Carte de France, the famous German 1 : 100,000,* as well as the British Ordnance maps (see Fig. 5), in the latter case combined with contours, however. The disadvantages of hachures are the facts, already noted, that while they indicate very clearly the general form of the ground they do not give as definite information as contours do, and that they cover up the map and obscure the other details in hilly country.

The **contour system** is used on the U. S. G. S. maps, Japanese Government maps, on the German and Swiss 1 : 25,000* maps, in conjunction with hachures on the English Ordnance, with shading on the new French map (see Frontispiece) and the maps of Norway, and with both hachures and shading on the latest edition of the German 1 : 100,000 maps. The principles of contours will first be discussed, then the various aids to their use explained.

Contours appear on maps as curving lines, in some places close together and in others far apart. Frequently they form closed figures of irregular shape and in many cases they do not close at all but pass off the edges of the map. These lines on the map represent imaginary lines on the ground that possess this peculiarity, namely, they join points which all have the same elevation. When we find a contour line numbered 1000 this means, therefore, that every point on this

* This refers to the scale of the map which is discussed in Art 10.

line is just 1000 feet or meters, as the case may be, above the zero level, which is usually the level of the sea. Contours are sometimes described as successive shore lines and it is true that the zero contour will be a shore line and that if we imagine the level of the sea to be raised 1000 feet the new shore line will be the 1000-foot contour and similarly for other contours. It is clear, therefore, that a man walking along the side of a hill and always staying at the same level, going neither up nor down, will be tracing out a contour line.

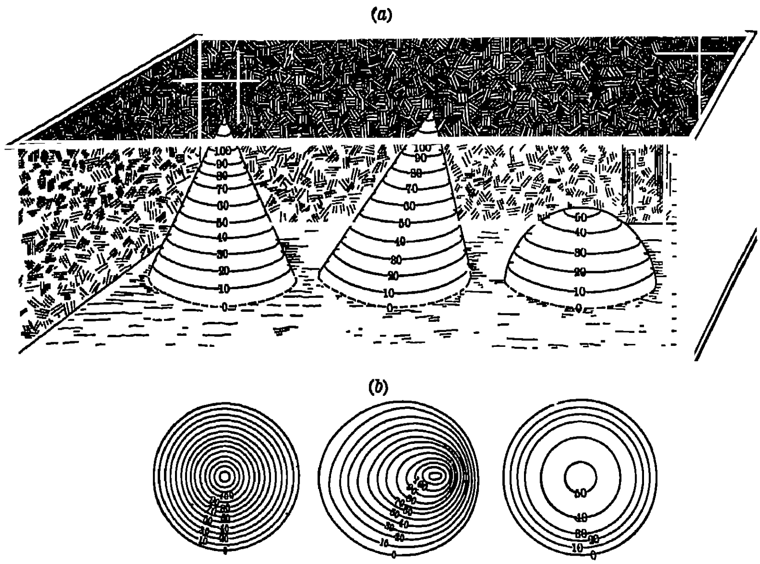


FIG 8.—Showing Principles of Contours

Some of the fundamental characteristics of contours can be shown by the experiment illustrated in Fig. 8.

(*a*) Shows a perspective view of a box the front of which is glass and in which there are placed three solids as shown, a right cone, a slanting cone and a hemisphere. The bottom of the box is assumed to be sea level, the zero level Water is put in the box so as to fill it to a depth of 10 feet and the new shore lines on the solids are drawn and marked "10." Another 10 feet of water is then put in giving a total depth of 20 feet and resulting in the shore lines marked "20." This procedure is followed until the solids are all submerged If we look down on the tank from directly above, the successive

shore lines on the solids will look as shown in (*b*). The three series of curves in (*b*) are therefore the contours of the three solids and the numbers on these contours indicate the height of the contours or shore lines above the zero level. Bearing this experiment in mind we can understand the following definitions.

The zero level is known as "datum." It is the level from which heights are measured. The numbers on the contours are their "elevations," that is, their heights, or distance measured vertically above the zero level or datum.

The depth of water was increased by 10 feet each time to secure the successive shore lines or contours. The difference in elevations or vertical distance, between any two adjacent contours, is therefore 10 feet This difference is known as the "vertical or contour interval" (frequently abbreviated to V. I.). On most maps the V. I. is the same for all the contours, but in some maps such as the International Map* it varies, and only the 100, 400, 600, 1000, etc., contours, for example, may be shown.

In reference to the datum it should be noted that the contours will be exactly the same whether the datum shown is used or any other datum differing from it by a multiple of the V. I. Only the elevation of the contour will be changed. Thus if we consider the water surface when there is 10 feet of water in the box as the zero level, or datum, the contours will all be the same but will be numbered ten less in each case, while the present zero contour will be an underwater contour and should be marked −10. If the level is assumed as zero when there is 15 feet of water in the box then both the contours and their elevations will be changed. Their shapes and spacing will remain the same, however, and they will be simply new curves drawn half way between the old ones. It is thus apparent that while it is interesting to know how high we are above sea level, and therefore to use maps for which the datum is sea level, that no important difference will be apparent in the contours if any other zero level is used. The marginal information on a map usually states the datum and gives the V I.

* See Appendix 1

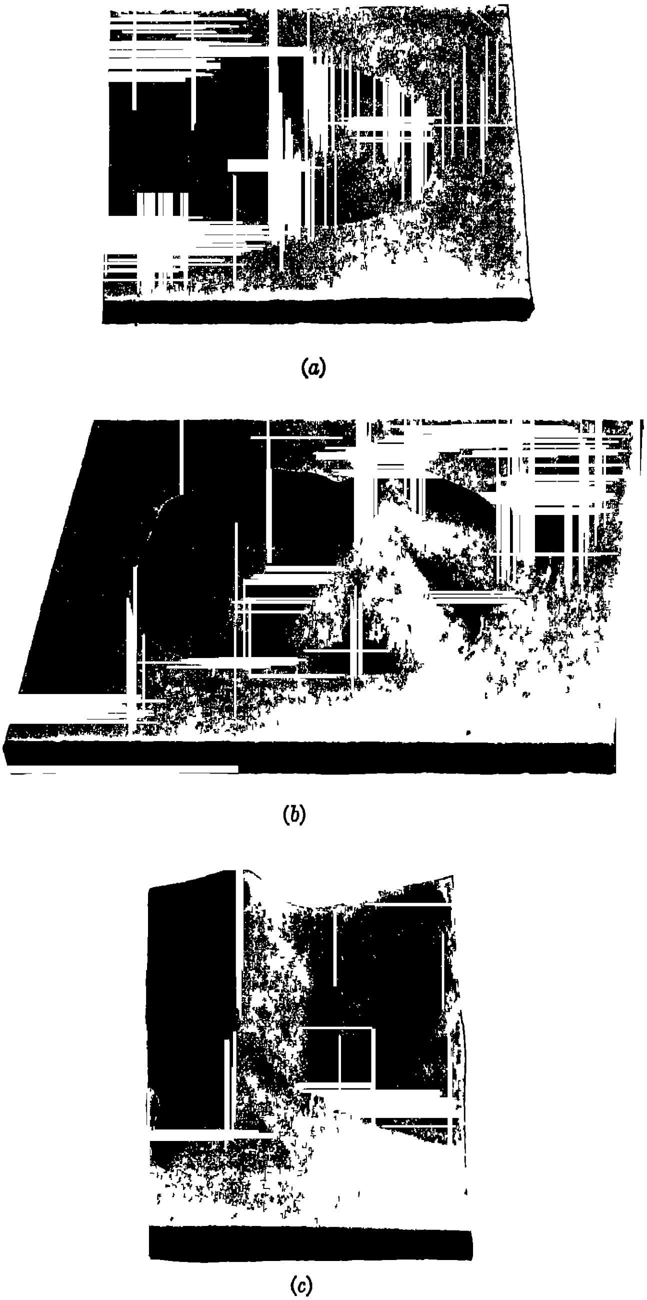


FIG 9 —Models for Contour Drawing

In connection with the contour elevation it should be noted that it must always be evenly divisible by the V. I. as it is simply a multiple of it. Thus we cannot have a 355-foot contour if the V. I. is 10 feet.

Referring again to Fig. 8*b* it is seen that the contours of the right cone are all concentric circles, and are evenly spaced, as the slope of the cone is the same all around and is uniform. Those of the slanting cone are ellipses and are spaced closer together on the right-hand side than on the left, as the slope is much steeper on the former than on the latter. In the case of the hemisphere the contours are all concentric circles, but the spacing varies, indicating that the slope is the same all around but is steep near the edges and flatter near the top. Hence we may say that contour lines close together indicate a steep slope and far apart a gentle slope, and that when they are evenly spaced the slope is straight, or uniform. It is also true that two contours of the different elevation will not ordinarily meet or cross. If, however, the right face of the second cone had been vertical the contours would all merge and if it had overhung the lower contours would curve inside of the upper ones. In nature this condition occurs only in those places where we have vertical or overhanging cliffs.

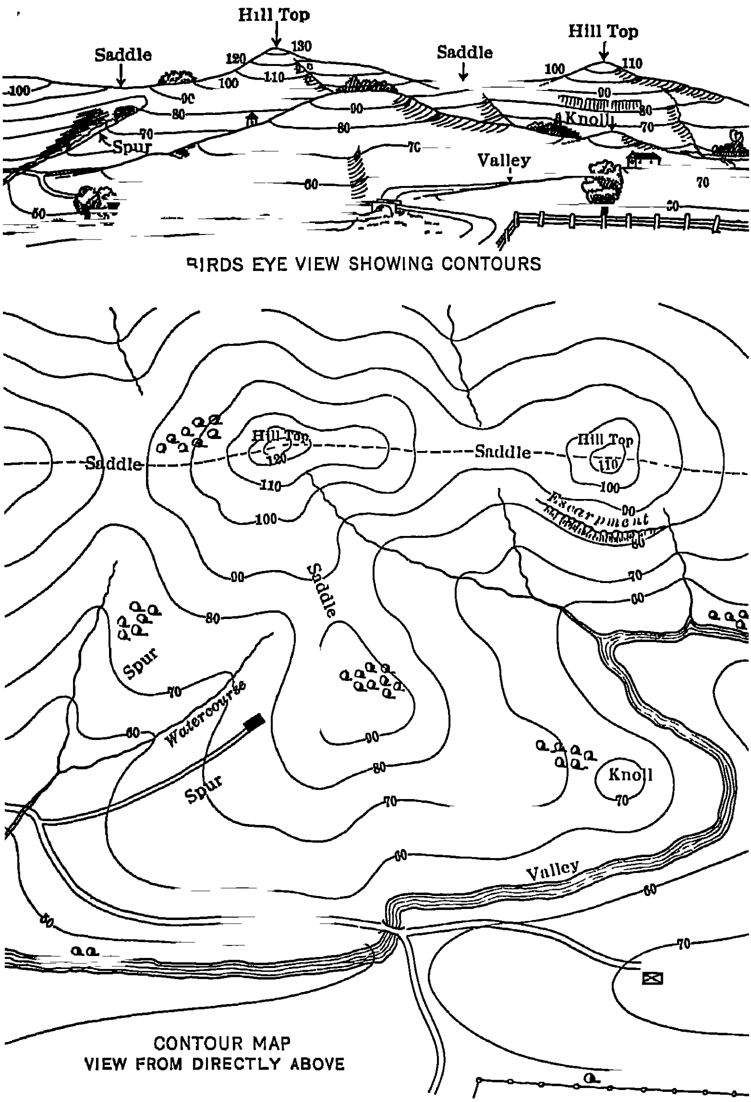
QUESTIONS

Questions 2 and 3 refer to Figs. 9*a* and 9*b*. These are photographs of plaster models* and the exercise consists in drawing sketch contours to represent the forms illustrated Assume that a V. I. of one inch is to be used and that the contours are to be drawn one-half the actual size of the model. Exact contours could only be drawn from measurements of the model itself, but sketch contours can be made from the Figures which will properly express the form of the models, the shape, relative slopes and heights.

1. Draw contours having an interval of one inch to represent a pyramid (square base with four sides equally inclined and terminating at the top in a point). Base is six inches square and height six inches
2. Fig 9*a* shows an island consisting of a hill of simple rounding form with a varying slope. The hill is 6½ inches high and 10 inches long.
3. Fig 9*b* shows another island consisting of two connected hills of different height (6½ and 7½ inches, respectively) and with several steep valleys running up from the sea The model is 14 inches long.

Refer to Fig. 13.

* See Appendix 2.



— After Bryant and Hughes

Fig. 10 —Contours and Contour Map

4. What is the V. I. of this map?
5. Which hill has a steeper slope, that above Magnolia (lower center) or that below, directly across the river?
6. Which is higher?

ART. 6. RELIEF—(*Continued*)

Fig. 10 shows a bird's-eye view of a section of hilly country with the corresponding contour map below. It is seen that contours in nature never have the perfectly regular shapes of Fig. 8*b* and furthermore they do not always form closed figures on the map. It is true that a contour must always close and form an irregular shaped closed figure but all contour lines do this only on maps of islands or entire continents. For example, every 10-foot contour would not close on a map of the United States, one would simply pass off the edges of the map as it would take a map of both North and South America to show this contour completely.

In studying Fig. 10 we therefore note that a number of the contours pass off the edges while others representing hills with downward slopes in all directions form closed figures. Portions of the land surface which project above the surrounding country, such as mountains, hills or knolls, and that are entirely within the limits of the map, will have closed contours. The dotted black line shown on the map, which practically coincides with the skyline in the bird's-eye view, marks the "divide" between two watersheds. That is, all surface water below this line on the map will drain through the small watercourses into the larger stream shown at the bottom of the map. The drainage of the area above this line will be toward the top of the map into the watershed of which only the upper ends of two small streams are shown. Running out from this main divide line are some minor spurs and ridges which run down the map from the hilltops. In connection with the lines of the divide and these ridge lines it will be noticed that they are higher in certain places than in others. The high points are hill tops and the sags are known as saddles, or cols

Fig. 11 shows the relation of the drainage and ridge lines for the country mapped in Fig 10 Streams are shown by

solid lines and the divide, ridge lines and spurs are dotted. It will be noted that the ridges form valleys in which the

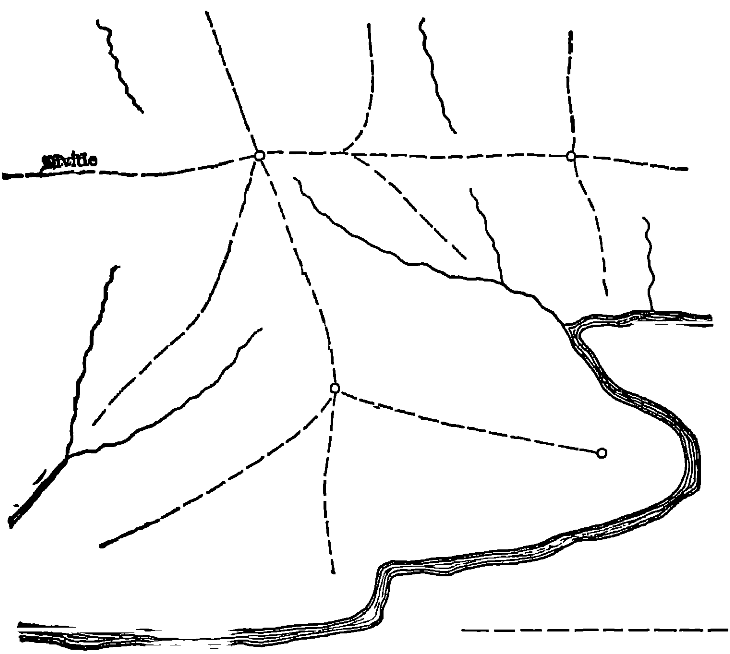


FIG. 11.—Relation of Drainage and Ridge Lines

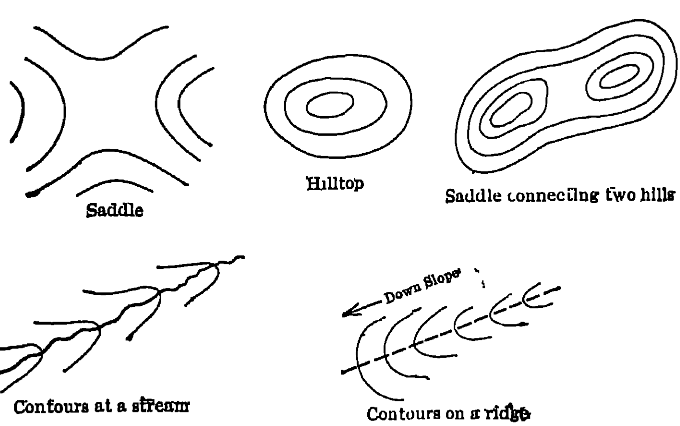


FIG. 12.—Characteristic Contours

streams are located. Some of the valleys are not sufficiently large to maintain streams, but in general the streams are

separated by ridges and there is a branching ridge system which fits in between the branches of the drainage system.

A study of the behavior of the contours at streams and ridges as illustrated by Fig. 10 shows that contours curve or bend upward, or toward the higher ground, at streams, while the opposite is true on ridges, that is, the curve of the contour points down the slope.

Fig. 12 shows the characteristic contours for hilltops, saddles, streams and ridges. While the type of drainage and relief described above is a common one there are many others, and the various sheets of the U. S. G. S. should be studied, along the lines above indicated, so as to bring out the relation of drainage and relief. This is one of the most important steps in developing an ability to visualize the country represented by a map, as well as in analyzing the relief for the purpose of mapping.

QUESTIONS

1 In the same manner as required in the previous questions referring to Fig. 9 draw sketch contours for Fig 9c This shows a model of a steep coast with a headland (about 3½ inches high) running out into the sea. The outer end of this headland has been cut off so as to form a steep cliff Note that most of the contours will run off the map as the model represents only a short length of the coast and does not show the spurs back to the top of the mountain range.

Refer to Fig. 13.

2 Point out a saddle on the ridge below and directly across the river from Magnolia? (Lower center.)

3 Do the contours to the right of Magnolia show a knoll?

4. Place a piece of tracing paper over Fig 13 and draw the line of the Potomac River and the divides and main ridge lines (all minor ridges not required) in a similar manner to Fig 11.

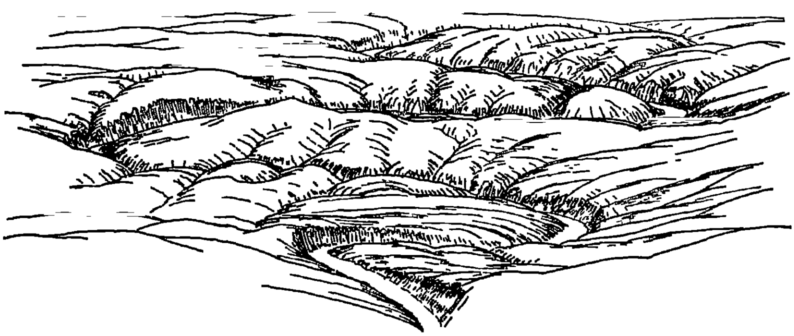
5. Outline on a piece of tracing paper the drainage basin, or watershed, of the stream flowing to the right, then downward, and entering the Potomac almost opposite Baird (left center)

6 Referring to Fig 7 place a piece of tracing paper over this hachure map and draw the drainage and ridge lines (see Fig. 11) of the rectangle above and to the right of Longuevillette.

ART. 7. RELIEF—(*Continued*)

Contours alone will not give the exact heights of hilltops. We can estimate the height of any point from the contours, but the exact height of an important hilltop, when given on a contour map, is shown by a spot height as on a hachure map. For example, the elevation of the peak below and to the left of Piney Point is given as 1988 in Fig. 13 (lower right).

To estimate the height of a hill when no spot level is given we proceed as follows. The highest hill on Fig. 10 must be over 130 feet as the 130 contour is shown below the top.

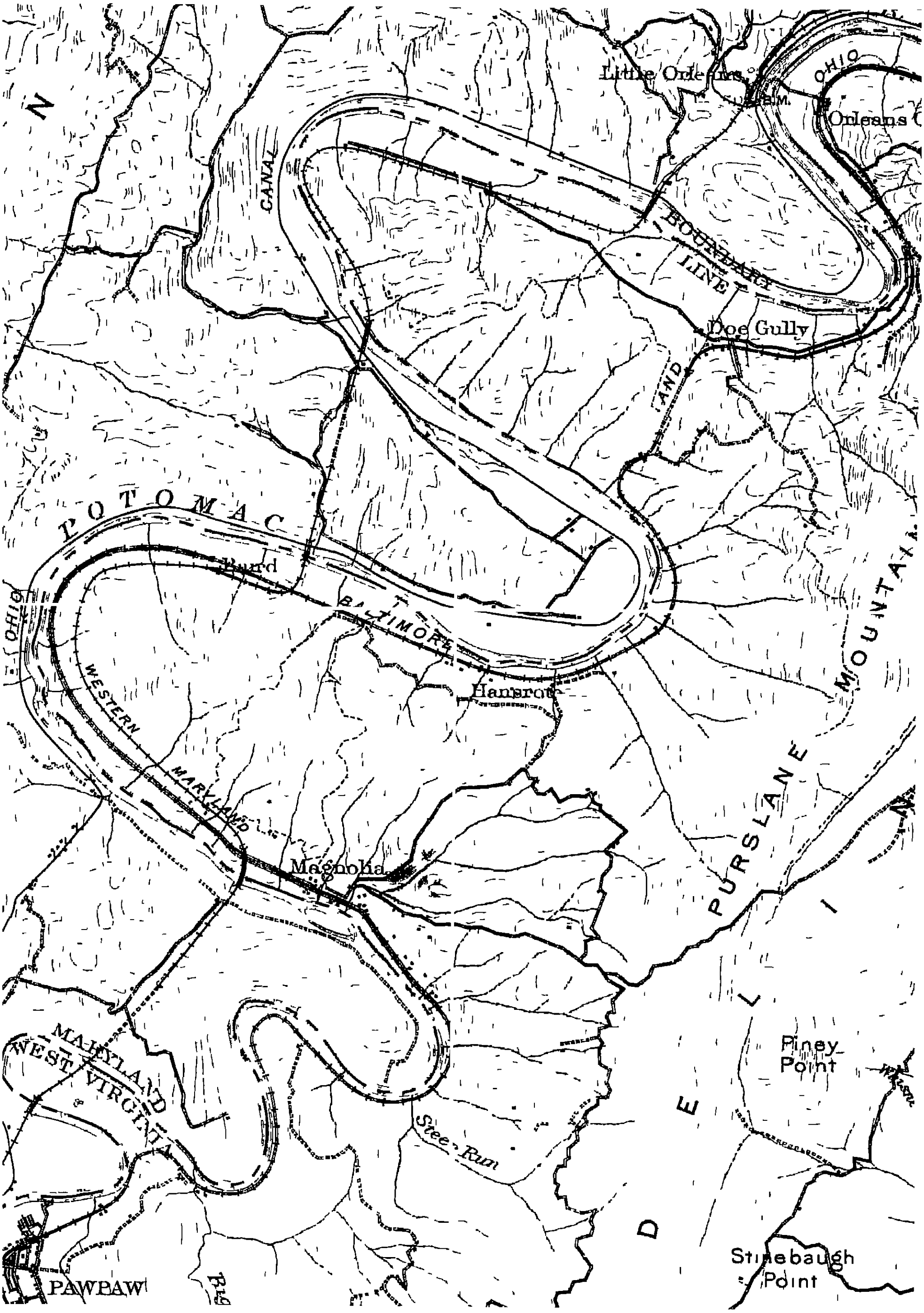


By F K Morris

FIG 13*a*—Birdseye View of Country shown by Map, Fig 13.

Also it must be less than 140, as the V. I. is 10 feet and no 140 contour appears. The best estimate would probably be 135 feet. A rough profile of the hill, such as is described later, will frequently lead to a closer estimate.

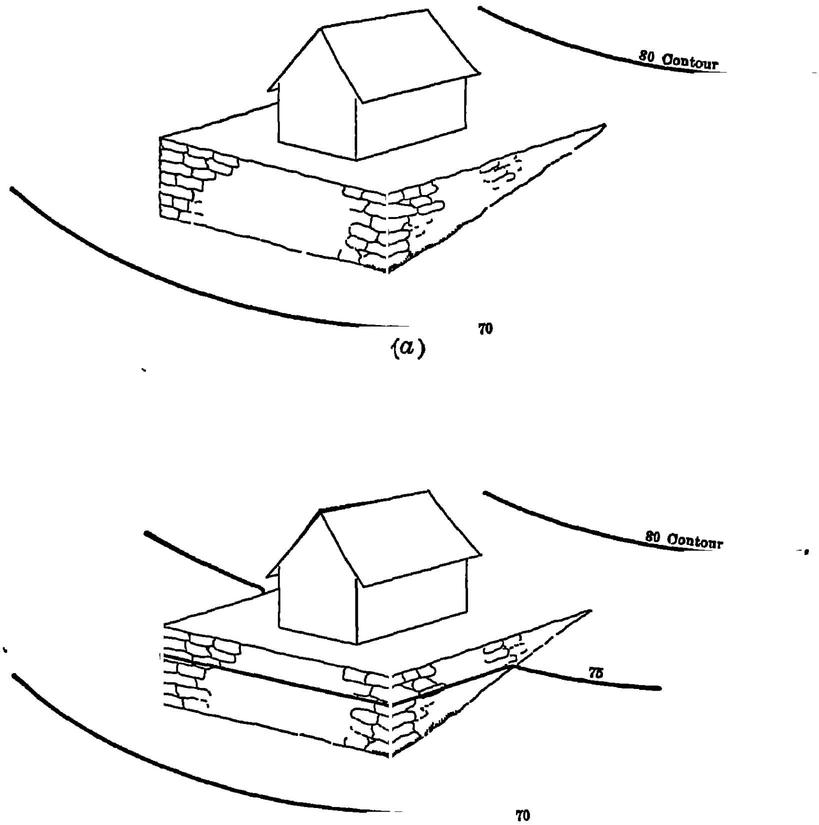
Depressions or basins below the general ground surface would be shown by closed contours just like hilltops. If the elevation of every contour was always given the relative heights could be easily determined. It is common practice, however, not to number all contours and on U. S G. S. maps; every fifth contour is drawn heavier and numbered. For this reason, and in order to make it clear when a contour shows a depression below the general ground level, short lines are drawn on the inside of the depression contour (pointing down the slope) similar to the lines used for embankments, but much



Little Orleans
B.M.
OHIO
Orleans
CANAL
BOUNDARY
LINE
Doe Gully
AND
POTOMAC
Purd
BALTIMORE
OHIO
Hansrote
WESTERN
MARYLAND
MOUNTAIN
PURSLANE
Magnolia
MARYLAND
WEST VIRGINIA
Piney
Point
Stee Run
D
E
L
I
Stinebaugh
Point
PAWPAW

shorter. There is thus a special depression contour sign.* A special hachure sign is also employed for cliffs on contour maps, and sand dunes, etc , are shown by fine stippling.

It is sometimes necessary to get the **elevation of points between contours,** and this is also done by estimation on the



(b)

FIG. 14 —Underfeatures.

assumption that the ground has an even slope between the contours. This assumption is generally justified for points along streams, railroads and roads, but in some cases may be in error. To get the elevation of the ground, at the house in the center of the map, Fig. 10, for example, we note that

* See Minneapolis Quadrangle, U S G S , for depression contours.

the house is located at a distance of about $\frac{7}{10}$ of the space from the 70 towards the 80 contour and if the ground rises uniformly a total of 10 feet in this distance it will rise $\frac{7}{10}$ of 10 or 7 feet to the house which is therefore located on ground at a probable elevation of 77 feet. If the house had been shown half way between the contours the elevation would have been 75 feet, etc. On the other hand, it is possible that the ground between the 70 and 80 contours may behave as shown in Fig 14*a*, that is, it may be located on a natural or artificial embankment in which case our estimate may be in error. It is obvious that the smaller the V. I. the smaller and consequently less important will be any such "underfeature" and the more accurate any estimate of an elevation. As illustrated in Fig. 14*b* a 5-foot interval would show the conditions much more closely. On the other hand, a map showing a small contour interval is expensive to make, as it requires very careful surveying, and the features brought out are relatively unimportant. The interval used also depends on the scale of the map. For landscape architecture an interval as small as 2 feet may be needed, 5 feet is commonly the smallest interval used and is found on many engineering maps, on maps drawn to a scale similar to the map in the folder in the back of the book, and on the detailed military maps of positions, trench systems, etc. The U. S. G. S. maps have in many cases a V. I. of 20 feet, which is smaller than is common in foreign maps. The smaller the V. I. the closer the contours will appear on the map. Such a map is easier to read than one with a larger interval.

QUESTIONS

Refer to the Hunterstown Sheet in folder in back cover.

1. What is the V. I on this map?
2. What is meant by 707 on hill west of Goldenville? (C-8)
3. Why is the same number, 647, on the two hills south of Guernsey? (A-8.)
4. What is the elevation of the hill just east of Friends Grove S H ? (A-7)
5. How much higher is Chestnut Hill (A-6) than Mt Olivet S H ? (A-7)
6. Which is higher, Plainview (B-5) or Biglerville (B-8)? How much?
7. What is the elevation of water in Conewago Creek at Bridge S. H.? (B-6)

8. Where is the highest point on road from Biglerville (B-8) to Heidlersburg (A-5)?
9. Where is the lowest point on this road? What is its elevation?
10. Where is the highest point on contour 540 between Boyd S. H. and Stock Farm? (E-8.)
11. Is the contour marked 500, east of Stock Farm (E-8) correctly designated?
12 Which way does the water flow in the Conewago?
13 When it is raining in Table Rock Station (C-8) in what direction does the water drain?

Refer to Fig 13.

14 Which way does the Potomac flow?
15. What is its elevation at Magnolia?
16. What is the elevation of the highest point shown on Purslane Mountain?

ART. 8. RELIEF—(*Continued*)

In using contour maps it is very important that we learn to visualize the relief from the contours. That is we must be able to form a mental picture of the conformation of the ground represented when looking at contours, and not simply see a mass of curving lines. Various aids have been used to assist those who use contour maps in forming a correct idea of the country represented.

From a contour map we may construct a correct and accurate **relief model** of the ground represented. These models are made in different ways, but Fig 15 shows an excellent but somewhat laborious method. Pieces of cardboard are cut out the exact size and shape of the contours shown in the contour map in Fig 15*a*. When placed over each other in the proper position these form a solid made up of layers as shown in Fig. 15*b* The thickness of the cardboard corresponds to the V. I. and, if the steps between these layers were filled with modeling clay so as to slope uniformly from the top edge of each layer to the top edge of the layer below, a true relief model would be formed. Time is seldom available to make relief models, but the layer idea is one which is often of assistance in forming a mental picture from the contours. It is the basis for at least two systems of contour rendering.

Fig. 16 shows the so-called "**layer system**" for contour maps The lower levels appear with a light tint which in-

creases with each succeeding layer and certainly assists in enabling us to picture the relative elevations and forms of the land. This system is common in many modern geogra-

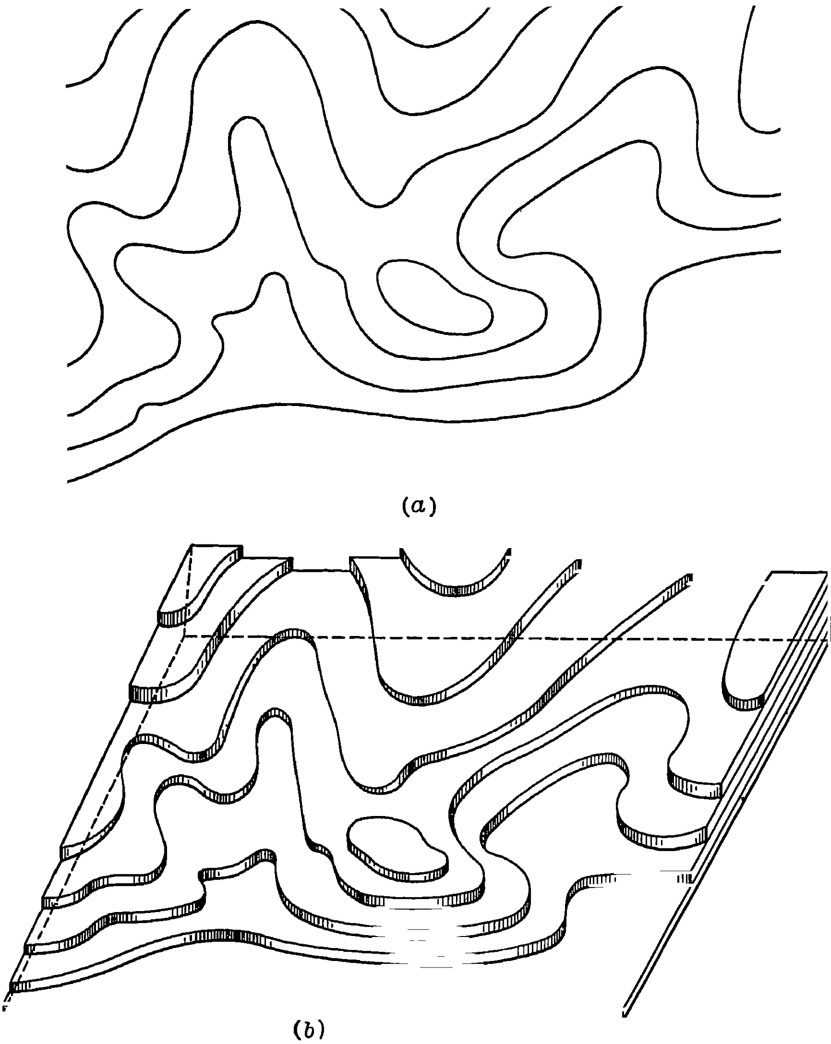


FIG 15.—Construction of a Relief Model

phies and is used on the International Map of the World. On this map the layers are tinted on a modified prismatic scheme of colors, the ocean being blue, lowlands green, fol-

lowed by yellow-brown tints of increasing strength with the highest peaks a deep magenta. The principal advantage of this system is that it allows instant comparison of the relative heights of separated sections of the country. For this reason it is particularly adapted to works on physical geography. As the number of color tints is limited and the process of printing expensive, it is not used on large-scale maps. Its principal disadvantage outside of cost is

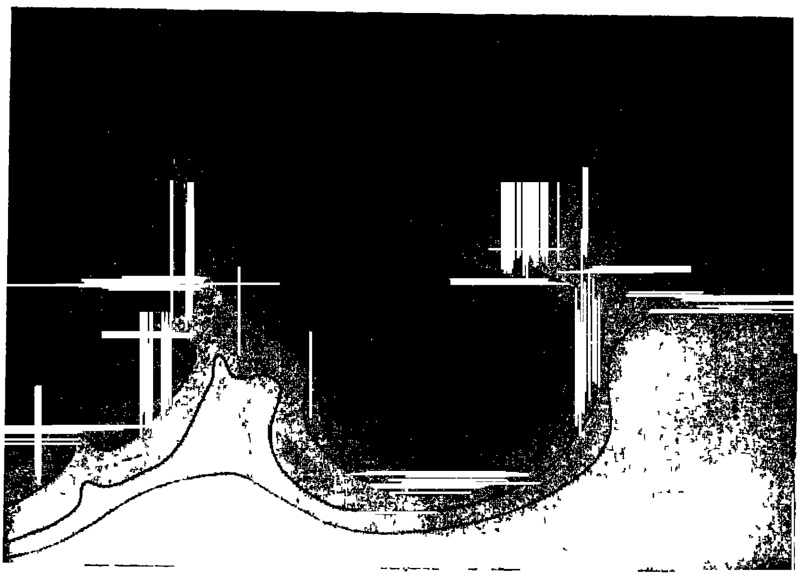


FIG. 16 —The Layer System for Contour Maps

that the tint is so deep for the high areas that it obscures the lettering and conventional signs A sheet showing a portion of the top of a high plateau with low relief would be colored a deep brown or magenta all over, and no emphasis would be possible to assist in picturing such relief as does exist.*

The so-called "oroscopic" system, which is also based on the layer relief model idea, is illustrated in Fig. 17. The system in the form shown, which is taken from Morrow's

*See some of the English maps of South Africa

"Contours and Maps,"* is applicable only to relief maps as the deep base tint obscures conventional signs. The scheme is based on layers with horizontal lighting at 45 degrees from the upper left-hand corner. The edges of those layers which are toward the light are shown white, while the edges away from the light are drawn in black. The system is quite a striking one and can be worked out without a ground tint by using two colors for the contour lines themselves, say a

FIG. 17.—Oroscopic System for Contour Maps.

light pink and deep red. No maps are made in this way, but it is suggested as an advantageous modification of the type shown.

Various methods of shading have also been used in connection with contour maps and these probably offer one of the most satisfactory solutions of the problem. The Norwegian maps use shading which is sometimes referred to as based on a vertical lighting system. It is simply the substitution of shading for hachures Thus on the English Ordnance maps,

* See Appendix

where hachures and contours are used, the hachure may be said to be line shading based on the principle that the steeper the slope the darker the shading. On the Norwegian maps the shading is produced not by lines but by a gray tint of varying intensity. The effect is the same as if the ground were lighted from directly above, the steep slopes which would reflect little light being dark, the gentler slopes lightly shaded and flat mountain tops or plains left unshaded.

The shading system used on the latest French maps is shown by the Frontispiece. It is based on a horizontal 45-degree lighting like the oroscopic maps but the intensity of the shading itself varies on the hachure plan as followed in the Norwegian maps. Each hill is treated by itself, the side which is in shade is shaded as noted above but the shadows cast by the hills are not shown.

QUESTIONS

1. Cut out pieces of cardboard and make a relief model of the contour map shown in Fig. 10 The shape of the contours can be taken off with tracing paper and transferred to cardboard with carbon paper. Use a square piece of cardboard for the base as shown in Fig. 15.
2. Assuming the light to be horizontal and coming at 45° from the upper left-hand corner (similar to the rays of the sun in the late afternoon in the summer) shade the lower left-hand corner of Fig. 13. Follow the French system. Use a soft pencil and be careful to blend the tint from light to dark. Note that the line of division between light and shade runs through the points where rays at 45° are tangent to the bends in the contours.

Art. 9. Direction

It is very important that a map show the direction of north and when using a map in the field the person using it must know the direction of north on the ground.

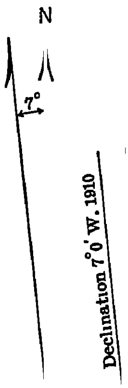


Fig 18.—Pointers

The direction of north on the map is sometimes given by an **arrow or pointer** such as shown in Fig. 18. On old maps, these pointers were often very elaborate, and a complete drawing showing the notation of the mariner's compass (see Fig. 21*a*) was frequently given. When parallels of latitude and longitude lines are shown (see Frontispiece and Figs. 5 and 13) the latter are meridians or true north and south lines. When no other information is given it is usually safe to assume that the top of the map is north, and the right- and left-hand edges are north and south lines, as most maps are made in this way.

The two lines shown in Fig. 18 are given because a compass is very commonly used in the field and the compass needle seldom points true north. The divergence between the two lines in the figure is the error in the pointing of the compass which is known as the **declination.** This error is due to the fact that the earth is a great magnet having a north and south pole just like a bar magnet, and these poles do not coincide with the geographic poles. The compass needle, pointing as it does toward the magnetic pole, does not give a true north direction and furthermore the angle between the compass north and true north varies not only with the location of the observer, but also with time. For example, in the United States there is a curving line running in a southerly direction and passing through the Great Lakes region and leaving the coast in South Carolina, and at any point on which the declination is zero and the compass points true north. At points like New York, east of this line, the needle points west of north and at San Francisco, west of the "agonic line," it points east. To illustrate the variation with time the case of Paris, where long records are available, is inter-

esting. In 1580 the declination was about $9\frac{1}{2}°$ east, and in 1810 it was $22\frac{1}{2}°$ west. Hence declination must be known and allowed for in using a map, although when merely general directions are required such as northeast, southward, etc., it makes little difference.

When using a map in the field to find one's way about, it is necessary (*a*) to know the direction of north and (*b*) to turn or "orient" the map so that its side edges will be north and south and the objects shown on the map will appear in the same direction as do the actual objects on the ground. For example, if you were in Goldenville (C-8) (see Hunterstown map in back of book), and wanted to go to Hunterstown (D-5) you would "orient" your map and take the road going in the same direction as the road to Hunterstown on the map, namely east. By keeping the map oriented you easily recognize the features shown as you go along the road.

The direction of a north and south line, or meridian, on the ground can be determined in several ways. One of the easiest is by using a compass as noted above. Release the compass needle and hold the instrument horizontal so the needle can swing freely. Turn the box so that the north end of the needle reads the declination and a line through the zeros of the scale on the box will be true north. For example, if the declination is 10° W we turn the compass so the needle points 10° west of north and the north and south line of the compass markings will then be a true meridian.

If a compass is not available a watch can be used. Hold the watch flat in the hand and with the hour hand pointing in the direction of the sun; a direction halfway between the hour hand and 12 is south. See Fig. 19. Remember that during the summer months all watches are one hour fast.

At night the North Star, called also Polaris, can be easily found in the heavens and a line from the observer to this star is very close to true north. Polaris can be located in the sky by means of the two "pointers" of the Big Dipper as shown in Fig. 20. Of course the position of the Big Dipper is not always that shown in the figure, as all the stars appear to rotate about Polaris as a center, due to the rotation of the earth,

and the Dipper will at times be above the Pole Star in a position that "would not hold water." Comparison of the compass with the north direction determined from Polaris is an excellent method of determining declination.

Some people have an ability in sensing direction and

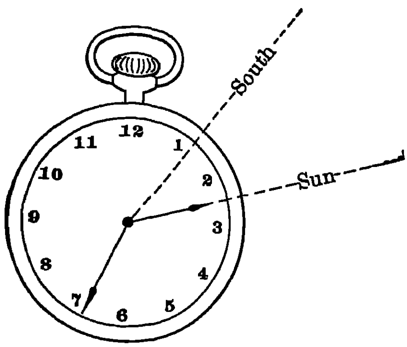


FIG 19.—Determination of South with a Watch.

when in the field, by day or night, always know the direction of north. This generally comes from a training in observing indications of direction such as the position of the sun, etc., that has become an almost unconscious habit. This sense of direc-

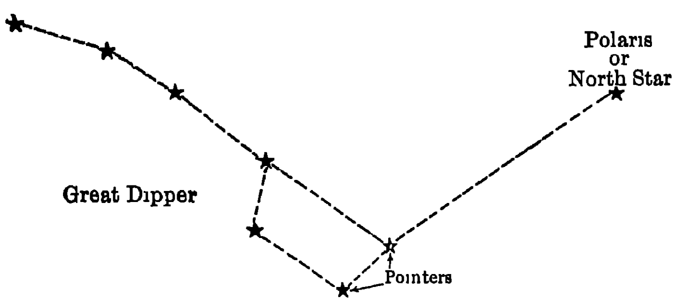


FIG 20.—The "Pointers" and the North Star

tion is entirely lacking in others and is a thing that children should early be taught to cultivate. Woodsmen note that moss prefers moisture and therefore grows best on the north side of trees, away from the sun. Certain plants such as the Compass Plant and Sow Thistle also arrange their leaves

or blossoms in certain directions and probably for similar easons.

Directions are stated in several ways. Fig. 21*a* shows the scale in a compass box divided to give **"the points of the compass."** We can thus say that the direction of one point from another is north north east (N N E), etc., (*b*) shows the

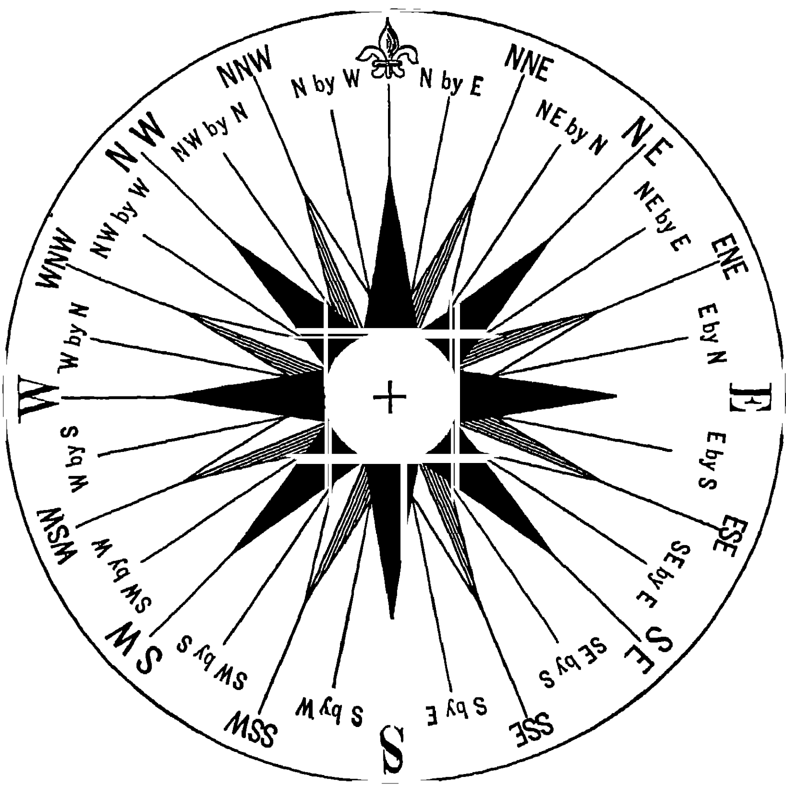


FIG 21*a*—Mariner's Compass

usual **compass bearing** graduation of the surveyor and we would speak of the same line as having a bearing of N $22\frac{1}{2}°$ E, meaning that it is $22\frac{1}{2}°$ from the North toward the East. Another method of stating the direction is shown in (*c*). This is known as the **azimuth** method and the circumference is divided from 0 to 360°. The zero point, or zero azimuth,

in surveying, is usually taken as North, but in astronomical work azimuths are measured from the south point. Note that when directions are given by azimuth, measured from a zero direction agreed upon, it is necessary to state simply the angle. Thus for the line mentioned above the azimuth

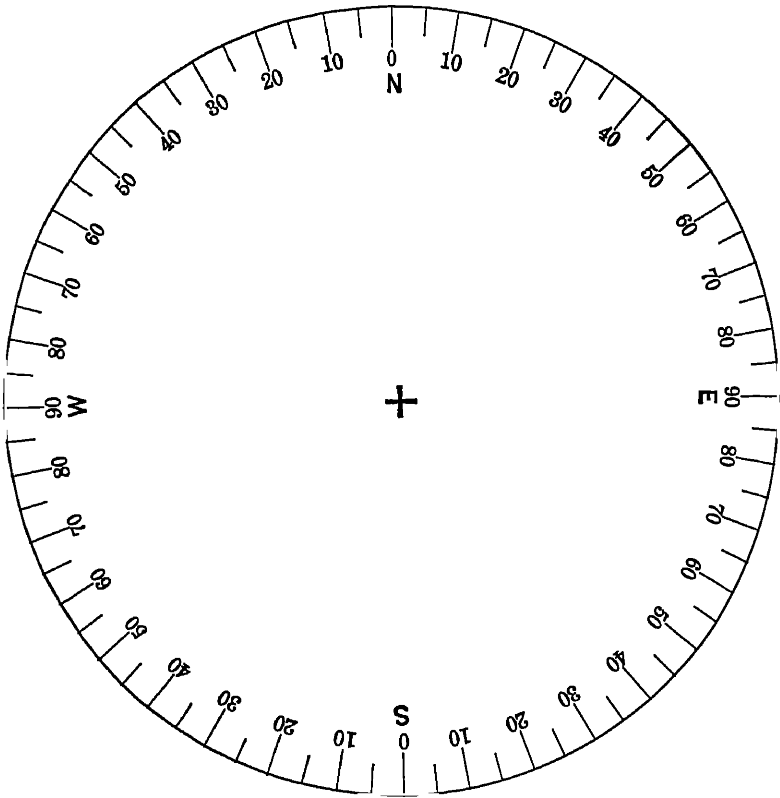


FIG 21b.—Surveyor's Compass Method

is simply $22\frac{1}{2}°$. The following comparison illustrates the three methods:

MARINER	SURVEYOR	AZIMUTH
N N E	N $22\frac{1}{2}°$ E	$22\frac{1}{2}°$
S E by S	S $33\frac{3}{4}°$ E	$146\frac{1}{4}°$
W S W	S $67\frac{1}{2}°$ W	$147\frac{1}{2}°$
N W	N 45° W	315°

To obtain the direction of a point B from a point A on a map place a piece of tracing paper over A and draw two lines on it showing both the north direction and the direction of B. This may then be placed over (*a*), (*b*), or (*c*) of Fig. 21 and the direction read off.

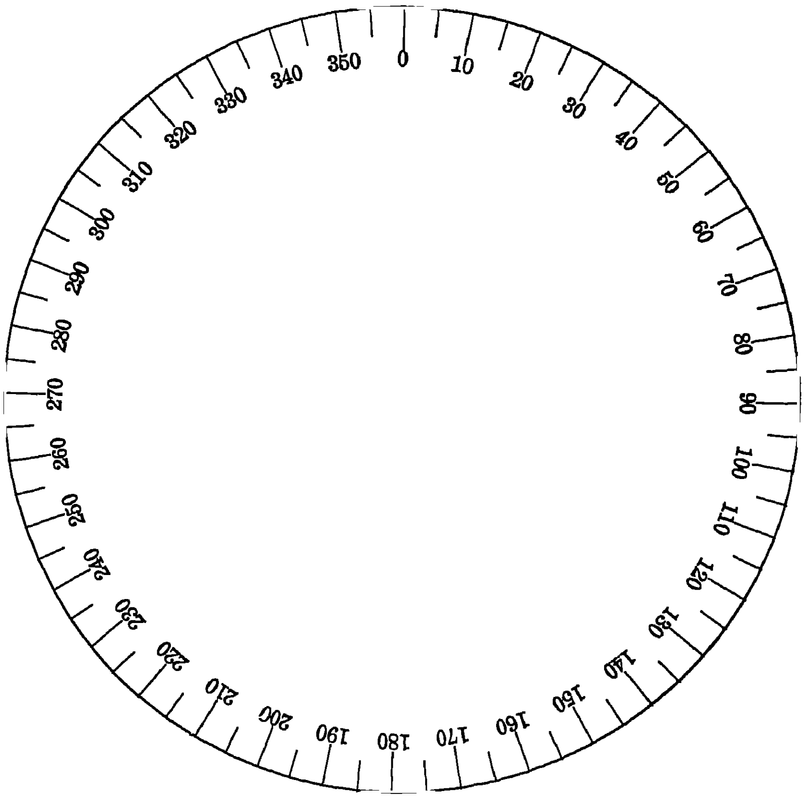


FIG 21*c*—Direction by Azimuth Method

QUESTIONS

1. Express the following directions by the three different methods (Mariner's notation, Surveyor's bearings and azimuth), N W by W, S 45°W, 270°.

   Refer to the Hunterstown Sheet in back cover pocket

2. State the general direction of Biglerville (B-8) from Plainview (B-5) by simply inspecting the map
3. What is the direction of Table Rock (C-7) from Biglerville stated in the mariner's manner

4. Describe the direction of Benders Ch (B-7) from the fork in the road at Table Rock by the surveyor's method.
5. Assuming north for zero azimuth describe the direction of Table Rock S. H. (C-7) from the fork at Table Rock.
6. Insert mariner's directions (using only the sixteen main points of the compass) in the following description of the road from Guernsey (A-8) to Table Rock (C-7) "From Guernsey go continuing past the first road coming in from . and turn the next corner going At four corners take road running continue past road leading . . and at four corners pass straight through continuing ... and passing road coming in from to Table Rock."
7. Write out similar description for the route from Plainview (B-5) to Hunterstown (D-5) passing Woodside S. H. (C-5.)

Art. 10. Scale

It has already been pointed out that maps are drawn so that the distance between any two points on the map always bears a certain relation to the corresponding distance on the ground. That is, one inch on the map may represent a mile on the ground and if we measure the distance between two towns on the map and find it is $2\frac{1}{2}$ inches, we then know that the actual distance on the ground is $2\frac{1}{2}$ miles. This statement of the relation between a distance on the map and the corresponding distance on the ground is known as the scale equivalent. There are two other ways of expressing the scale of a map, by stating the Representative Fraction and by giving a graphical or reading scale. The latter is discussed in Art. 11. In many cases the marginal information on the map states the scale in all three ways.

The Representative Fraction (usually abbreviated to R. F.) of a map is simply the ratio between any distance on the map and the corresponding distance on the ground. Thus if one inch on the map represents a mile on the ground the R. F. of the map is 1: 63,360. This is true because one mile = 5280 feet = 63,360 inches, and one inch on the map must represent one mile or 63,360 inches on the ground, hence the ratio between one unit on the map and the number of the same kind of units that it represents on the ground is 1 : 63,360. Stated in another way this means that the map is a picture of the ground reduced to one sixty-three thousand three hundred

and sixtieth of its actual size. The R. F. being simply a ratio of size it is clear that it makes no difference what unit is used the ratio is the same. For example, we may write one inch on the map equals 63,360 inches on the ground or one foot or yard or meter equals 63,360 feet or yards or meters on the ground.

Knowing the scale equivalent we can easily find the R. F. or knowing the R. F. we can find the scale equivalent. The operation involves only division and multiplication and is illustrated by the two following problems:

The standard scale for U. S. Military maps of special features is 6 inches = 1 mile. What is the R. F.? We proceed as follows:

Six inches on the map equals one mile on the ground but one mile equals 63,360 inches, hence

Six inches on the map equal 63,360 inches on the ground or one inch on the map equals $\frac{63360}{6}$ or 10,560 inches on the ground, hence the ratio between one unit on the map and the number of the same kind of units it represents on the ground, or the R. F., is 1: 10,560. Again:

The Carte de France is drawn with an R. F. of 1: 80,000. How many miles on the ground are represented by one inch on the map.

If the R F is 1. 80,000 we can write,

One meter on the map equals 80,000 meters on the ground, or

One yard on the map equals 80,000 yards on the ground, or

One foot on the map equals 80,000 feet on the ground, but for our purpose it will be best to use the relation,

One inch on the map equals 80,000 inches on the ground and since a mile is 63,360 inches we have,

One inch on the map equals $\frac{80000}{63360}$ or about $1\frac{1}{2}$ miles on the ground.

It will be obvious from the above that while a map can have but one R F., we can express its scale by innumerable scale equivalents. That is, we may say that one inch on the map equals $1\frac{1}{4}$ miles on the ground or one centimeter on the map equals 0.8 of a kilometer, or one inch equals 2 kilometers, or one centimenter equals half a mile, etc. These expressions

are all simply different scale equivalents for a map having an R. F. of 1: 80,000. They are easily obtained if we know the relations of the different units employed. Thus a kilometer is 100,000 centimeters and since one centimeter on the map represents 80,000 centimeters on the ground, it must represent 80,000 ÷ 100,000 or 0.8 of a kilometer. Also since one mile equals 1.61 kilometers and one inch on the map represents 1¼ miles on the ground, it must represent 1¼ times 1.61 or practically 2 kilometers, etc.

These problems in scale relations are, as stated above, simple arithmetic, but are often confusing to students. They must be thoroughly understood, however, as a proper understanding of scale is of vital importance in using maps. The relation of the scale adopted for a map to the use to which the map is to be put, the size of the individual sheets of a map and convenience in handling, the amount of detail that is shown and the conventional signs, as well as to the method of showing relief and the V. I. of contour maps has been discussed. (See Introduction and Arts. 2, 3, and 7.) The actual relation between the scale and contours of a map, and the ground represented cannot be taught from books It comes only from actual practice in using a map in the field where it can be compared with the ground, and the student gradually acquires the ability to picture in his mind the ground represented when looking at a map.

The following tabulation gives some of the scales used on topographic maps:

Kind of Map	Scale	Relief
Landscape Design	1 in = 25 or 50 ft	Contours V I 2 or 3 ft
Engineering Maps for roads, railroads, etc	1 in = 100 or 200 ft	Contours V I 5 ft
U S. Army fortification and other detailed maps	12 in = 1 mile (1 in = 440 ft)	Contours V I 5 ft
French maps of the Western Front	1 5000 (1 in = 416⅔ ft)	Contours V I 1 to 5 meters
U S Army Position Sketches and Maneuver maps also large scale British Ordnance Map	6 in = 1 mile (1 in = 880 ft)	Contours V I. 10 ft for former
English Trench Maps and Artillery Maps	1 10,000 (1 in. = 833⅓ ft)	Contours V I 10 meters

Kind of Map	Scale	Relief
U S Army Road Maps or Sketches	3 in = 1 mile (1 in = 1760 ft)	Contours V. I. 20 ft
German and Swiss large scale Govt Maps	1 25,000 (1 in = 2083⅓ ft)	Contours V I. 5 to 10 meters
U S G. S Maps (Important Areas)	1· 62,500 (1 in = 5208⅓ ft)	Contours. V I usually 20 ft
New French Maps	1 50,000 (1 in = 4166⅔ ft)	Shaded Contours V I = 10 meters
English Ordnance Maps (Standard Edition)	1 in = 1 mile (1 in = 5280 ft)	Hachures with contours. V I 100 ft
Carte de France	1. 80,000 (1 in = 6666⅔ ft)	Hachures
German Standard Govt Map	1 100,000 (1 in = 8333⅓)	Hachures
U. S G. S (Unimportant Areas)	1 125,000	Contours. V I 10 to 200 ft
U S G S (Plains)	1 250,000	Contours V I 10 or 20 ft
International Map of the World	1 1,000,000	Contours with layer system V I variable

QUESTIONS

1 If the R. F. of a map is 1· 75,000, how many miles on the ground does one inch on the map represent?

2. How many inches would be required on the above map to represent one mile on the ground?

3. How many kilometers on the ground would one centimeter on the map represent?

4 What would the answers to questions 1, 2 and 3 be if the R F. was 1 40,000?

5. Suppose that the margin of a map has been torn off and you do not remember the scale You do remember, however, that the distance between two towns is 2¼ miles and you find by measuring that this distance on the map is 6¾ inches What is the R F ?

6. Complete the following tabulation:

R F	Scale Equivalents	
1 21,120	or 1 in = 1760 ft	or 3 in = 1 m
	or	or 6 in = 1 m
	or	or 12 in = 1 m
1 62,500	or .	or
1 20,000	or	or

Art. 11. Scales—(*Continued*)

Fig. 22 shows the reading or **graphical scales** printed on the bottom margin of those U. S. G. S. maps which are drawn with a R. F. of 1: 62,500. Scales of this kind may be made for any map and furnish the easiest means of measuring distances from the map in any unit.

For example, the distance in a straight line between the railroad stations at Hansrote and Baird, Fig. 13, is required. The edge of a piece of paper is placed on the line between these points and the points are marked on the paper. This paper is then compared with the mile scale of Fig. 22. We place one mark opposite the zero of the scale and note that the other mark comes between the 1- and 2-mile divisions, thus indicating that the distance is between 1 and 2 miles. To read the distance to tenths of a mile we place one of the marks on the paper even with the 1-mile division of the scale and obtain the tenths, and if we wish to we can estimate the hundredths, by reading the closely graduated portion of the scale toward the left from the zero mark. The distance is read directly as a little over 1.8 miles or may be estimated as 1.82 miles.

Graphical scales are made in this way with large divisions and an extra unit closely divided at the left end in order to make them simpler and make it unnecessary to divide the entire scale into the smaller units. The distance in kilometers can be read in the same manner from the kilometer scale of Fig. 22 and is 2.94 kilometers. Instead of using a piece of paper to compare distances with the scale a copy of the scale may be drawn on a piece of paper and the distances can be measured directly on the map.

Distances in a straight line are required in taking from maps ranges for artillery fire, etc. More common problems, however, require distances between two points along a road. For example, what is the distance by road between Hansrote and Magnolia, Fig. 13? This is obtained by transferring to a strip of paper the successive short straight lengths which make up the total length. On this particular road there are a dozen or more of these lengths and on a curved line such as

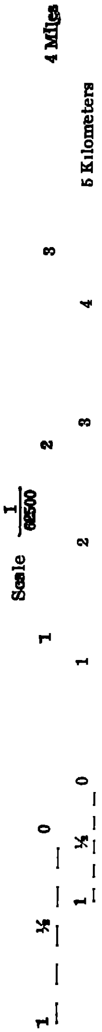


FIG. 22.—Graphical Scale for U. S G S Maps.

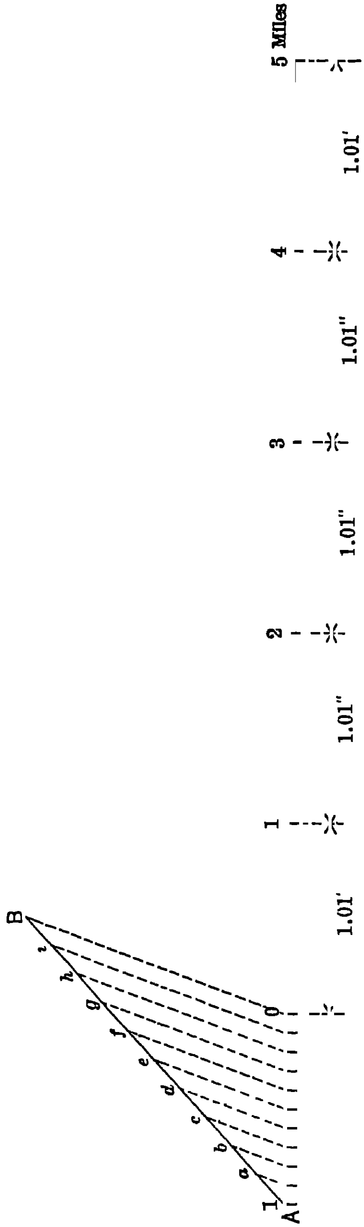


FIG. 23.—Construction of Graphical or Reading Scale.

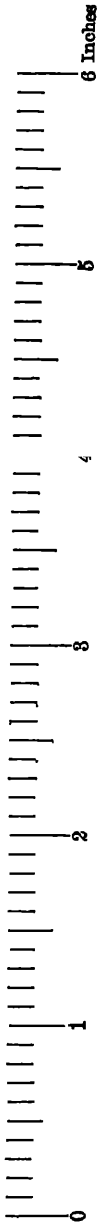


FIG 24.—Engineer's Scale. Inches and Tenths.

a railroad, canal or stream we have to arbitrarily divide the total distance into a series of short lengths which we consider as straight. A special "measuring wheel" is made by instrument manufacturers for measuring curved distances, or a piece of thread may be placed along the line then straightened out and measured. Thread will often stretch, causing an error, unless the same pull is used on it when measuring and comparing.

The construction of a graphical scale is best explained by a problem. Thus the mile scale of Fig. 22 is made as follows: The R. F. of the map is 1:62,500 and we must find how many inches on the map represent one mile on the ground. When this value is found, in this case 1.01 inches on map equals 1 mile on the ground, the scale is constructed by laying off successive lengths of 1.01 inches as shown in Fig. 23 and dividing the end length into ten parts. Now the R. F. being 1:62,500 one inch on the map will represent 62,500 inches on the ground. But one mile is 63,360 inches, hence a mile on the ground will be shown by 63,360 divided by 62,500 or 1.01 inches on the map, giving the distance required for the major divisions of the scale, which are then laid off with a ruler or scale divided into inches and tenths such as is shown in Fig. 24 (an engineer's scale). The sub-division of the left-end length of the scale into ten parts can be done by trial or by the construction shown in Fig. 23. Any line AB is drawn ten units in length and these units marked as at *a*, *b*, *c*, etc. B is connected with the zero mark. Lines are then drawn parallel to the B-zero-line through each of the points *a*, *b*, *c*, etc., thus dividing the length A to zero into ten equal parts.

The accuracy of distances scaled from maps depends upon several things. First the care with which the distances are measured and compared with the scale. For accurate work a pair of dividers should be used. Secondly, points shown on the map may or may not be shown in their exact location due to errors in making the map. Great accuracy in locating all points shown on a map is costly and it is customary to show some unimportant features only in their approximate positions. For example, all survey points, such as triangulation

stations, are very accurately located and drawn. Roads are also usually carefully surveyed and drawn. Hence distances between points on roads are quite accurate, probably at least to 1 or 2%, while in scaling distances between survey points the error is all in the scaling, not in the map. Other points are subject to more or less error, and a method followed in obtaining accurate distances is to measure on the map the distance between two points thought to be well located and near the required points. Then measure on the ground the actual distance between the required points and the points selected on the map and add to or subtract from the distance scaled from the map the distances measured on the ground.

The accuracy of positions shown on the map also depends on the condition of the map. The paper on which the map is printed expands, or contracts, with climatic changes and due to the process of printing. For this reason it is always best to use the reading scale printed on the sheet itself in measuring distances. In highly accurate artillery work the map is cut up into small sections along the latitude and longitude lines and these sections are then pasted in their proper position on a zinc sheet on which the latitude and longitude lines have previously been carefully drawn.

Another feature which influences the accuracy of both direction and distance in long distances is the projection (see Art. 2) of the map. This feature is not important except in very accurate work.

QUESTIONS

1. Construct a graphical or reading scale having main divisions of 1000 yards' value and an end portion graduated to 100 yards for use with a map drawn with a R F. of 1 20,000 Give all calculations in neat form and construct the scale by the method of Fig. 23, using the engineer' scale of inches and decimals shown in Fig. 24.

Refer to Hunterstown Sheet in back cover.

2. What is the distance in miles across this map from east to west?
3. What is the distance from Biglerville (B-8) to Goldenville (C-8)?
   (a) In a straight line? (b) By road? (c) By railroad?
4. What is the distance from Bridge S. H to Herschey Mill (B-6) by farm roads?

5. Enemy has artillery on Chestnut Hill (A-6). Can they shoot to Plainview? (B-5.)*
6. Enemy has infantry on Chestnut Hill. Can they shoot to Plainview?*
7. How far does Biglerville (B-8) extend along the road from east to west in hundreds of yards?
8. What are the dimensions in yards of the orchard southwest of Hunterstown? (D-5.)
9. Assuming that the trees are 5 yards apart, about how many are there in the orchard? Does each circle represent a tree?

* The classification of ranges is given as follows in Field Service Regulations Appendix 7, p. 205.

Range	Rifle, Yards	Field Artillery, Yards	Heavy Artillery, Yards
Distant	Over 2000	Over 4500	Over 6500
Long	2000 to 1200	4500 to 3500	6500 to 4000
Effective	1200 to 600	3500 to 2500	4000 to 2500
Close	Under 600	Under 2500	Under 2500

CHAPTER II

HOW TO GET CERTAIN INFORMATION FROM A MAP

Art. 12. Sections and Profiles

Sections and profiles are easily constructed from contour maps and reduce the information shown on such maps

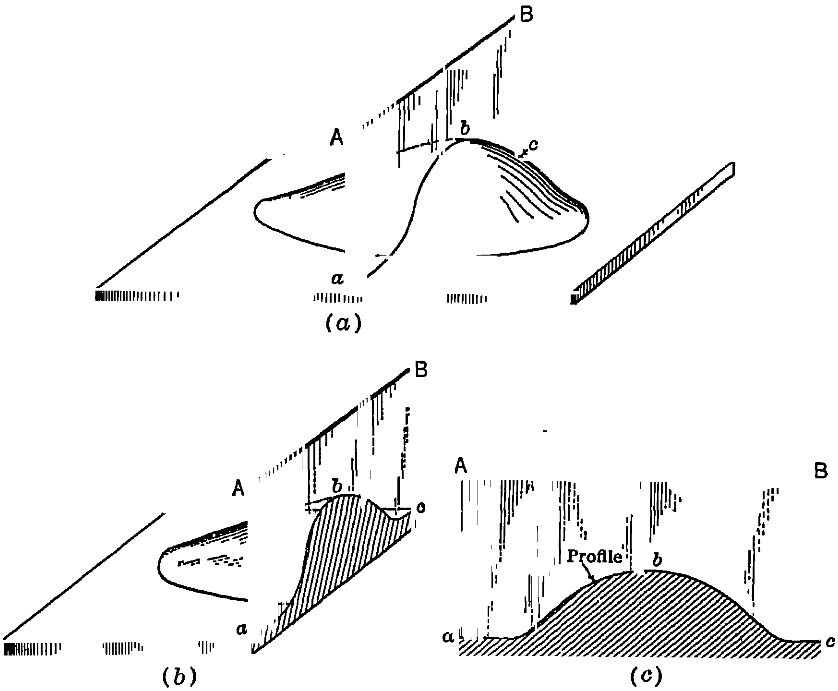


Fig 25 —Section and Profile

to a form which is often more convenient and better for certain kinds of work than the map itself. In using maps time is not always available to construct profiles, but the

ability to picture in the mind the approximate form and characteristics of a section or profile along some line on the map is very important.

Fig. 25 illustrates the terms, **section and profile.** Thus Fig. 25*a* shows a model of a rounded island similar to Fig. 12*a*. Imagine a vertical plane, AB, to cut through the model on the line *abc* like a large knife. When the right-hand portion of the model is removed it would look like Fig. 25*b*. If the

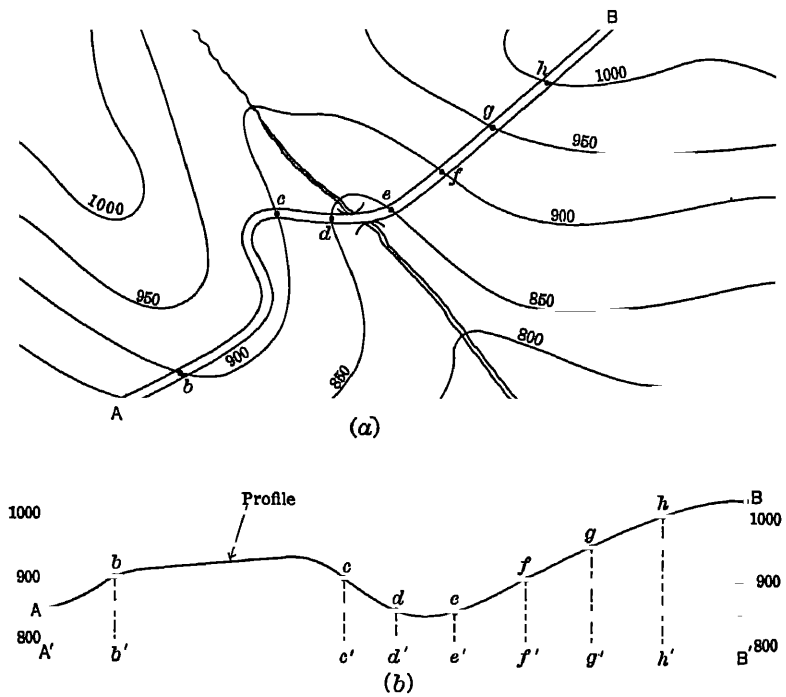


FIG 26 —Construction of a Profile

model is now turned around so that the plane AB is directly facing the observer, Fig. 25*c* shows the result. The portion of this figure marked by line shading (cross-hatched) is a section of the model on a plane through A and C and the top boundary of the section, which is shown by a heavy line lettered *abc* in Fig. 25*c*, is a profile across the model on the line *ac*. A profile is therefore a curving line which shows the ups and downs of the surface along a line on the model or

in reduced scale, a line on the ground represented by the model. Sections are usually drawn showing the intersection of the ground and an imaginary vertical plane as is illustrated in Fig. 25, but profiles may be drawn for any line on a model or the ground, curved or straight, and it is only when the line is straight that the profile represents the intersection of a vertical plane with the surface of the ground and is therefore the top boundary of a section.

For example, Fig. 26*a* shows a contour map. A profile may be drawn of the road between A and B. This profile will show the ups and downs of a line on the ground which follows the center of the road from A to B, as is shown by Fig. 26*b*. It is made as follows: By an examination of Fig. 26*a* it is noted that the lowest point on the road is at the bridge and is just below 850, while the highest point is B which is over 1000 feet. A horizontal line is drawn on a piece of paper to represent an elevation of 800 feet and is marked 800. Other horizontal lines are drawn above this line at a convenient spacing to represent 850, 900, 950, and 1000 feet. A point is selected at the left end of the paper to represent the point A on the map. The elevation of A is seen, from the map, to be 850 feet and it is plotted at A on the profile Fig. 26*b*. The distance *Ab*, *bc*, *cd*, *de*, *ef*, *fg*, *gh*, and *hB* are measured from the map along the center of the road and laid off on the profile as $A'b'$, $b'c'$, etc. The point *b* on the map is seen to be 900 feet elevation so *b* on the profile is plotted directly above b' at 900 feet and similarly for the other points. These points *A*, *b*, *c*, etc., on the profile are then connected by a smooth, curving line which thus gives the ups and downs of the road between A and B as required. Note that we must estimate the height of the road between *b* and *c* and at such points as the bridge in order to draw the profile properly between the plotted points *b* and *c* and *d* and *e*.

Special paper, known as profile paper, can be obtained for plotting profiles. The steps in the process, as described above, are 1, Selection of a base line, or bottom line, for the profile which will be lower than the lowest point on the profile so that the profile will not run below the lower edge of the profile paper. It is of course unnecessary and a waste of

paper to make the bottom of the paper datum or zero level. 2, The horizontal scale of the profile is generally made the same as the map, but a vertical scale must be assumed. Often the most convenient plan is to draw lines on the paper, or in using profile paper consider the space between two horizontal lines, as representing the contour interval. This will, in most cases, exaggerate the vertical scale. That is, one inch measured vertically will represent a smaller number of feet than one inch measured horizontally. Such a procedure does not produce a "natural" profile, but it does result in accentuating the hills and slopes which does not detract from the usefulness of the profile and makes it easier to work with. Ordinarily the ratio between the horizontal and vertical scales is made from 5 to 10, as this has been found to give a suitable profile. Thus the map shown in Fig. 26*a* may be drawn to a scale of three inches equals one mile and the horizontal scale of the profile, Fig. 26*b*, will be the same, namely, 1760 feet to one inch. Now the greatest difference in elevation on this profile is about 200 feet, hence, if the vertical scale was made the same as the horizontal, the point B on the profile would be shown about $\frac{1}{8}$ of an inch (1760÷200) above A. This would be the natural profile, but the exaggerated profile, drawn so that one inch equals 300 feet or six times greater than the horizontal scale, shows the ups and downs of the ground much more clearly and is quite as useful.

The use of profiles in connection with problems in slopes and visibility is the subject of the next four articles.

QUESTIONS

1. Draw a profile of the line of the divide of Fig 10 Make the horizontal scale the same as that of the figure, which can be taken as 12 inches = 1 mile and the vertical scale 1 inch = 50 feet
2. What is the ratio of exaggeration in question 1?
3. Draw a section directly across Fig. 13 on the latitude line shown Note that only the hundred-foot contours need be plotted except at the tops of hills and bottom of valleys where the elevations should be estimated. Use a horizontal scale of the same as the map and a suitable vertical scale.
4. Draw a profile of the road from Hem to Fienvillers on Fig. 7. This is a hachure map and the profile will necessarily be less accurate than that

obtained from a contour map, but at the same time can be made with considerable accuracy by careful study and estimation.

NOTE The horizontal and vertical scales must always be given as part of the title of a profile.

ART. 13. SLOPES

One of the most important things to determine from a topographic map is the slope or grade of the hills, roads, railroads, etc. It is necessary to understand how slopes are described before discussing the various ways in which a knowledge of slopes is useful.

Fig. 27 illustrates by cross-sections the three forms in which slopes are stated, namely: *a*, by giving the slope angle, *b*, by the slope fraction, and *c*, in per cent.

The **slope angle** is shown in Fig. 27*a*, and is the angle between the sloping surface and the horizontal. We may therefore speak of a slope of 3°, meaning an angle BAC of 3°.

The **slope fraction or ratio** is the ratio between the rise, or amount we go up, and the horizontal distance, or base, which corresponds to this rise. Fig 27*b*. For example, the horizontal distance between two contours on a map having a V. I. of 10 feet may be scaled from the map and found to be 100 feet. If the ground surface slopes uniformly between these two contours its slope is 10 in 100 or $\frac{1}{10}$ which is the slope fraction, the rise being 10 for a base, or horizontal distance, of 100. Engineers frequently speak of slopes of embankments as 1 in $1\frac{1}{2}$ or 1 on $1\frac{1}{2}$ for

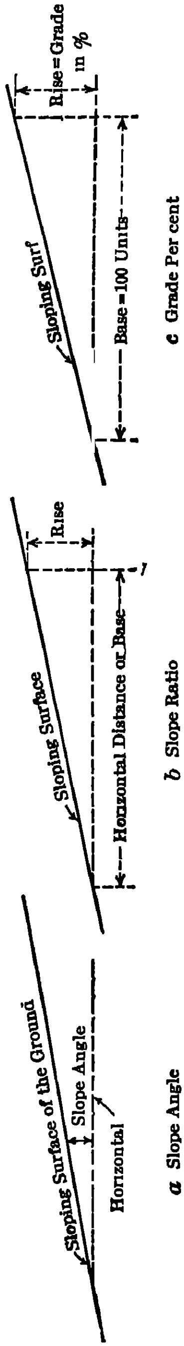


FIG 27.—Methods of Expressing Slopes.

example. This is a common slope for railroad embankments and the statement means that the rise is 1 foot or yard for a base of $1\frac{1}{2}$ feet or yards, or corresponding unit. In other words instead of stating the slope fraction, which in this case is $1 \div 1\frac{1}{2}$ or $\frac{2}{3}$, they state the rise and base.

When giving the slope of a road or railroad it is quite common to give the grade in *per cent.* That is give the units rise for a base of 100 units Thus in the case of the two contours mentioned above the rise is 10 feet in 100 feet, hence the grade is 10%. See Fig. 27*c*.

It is obviously quite easy to change from a slope fraction to per cent or vice versa. Thus a slope fraction of $\frac{1}{6}$ means a rise of 1 for a base of 6 and if the base was 100 the rise would be $100 \div 6$ or $16\frac{2}{3}$, hence the grade is $16\frac{2}{3}\%$. Or the slope

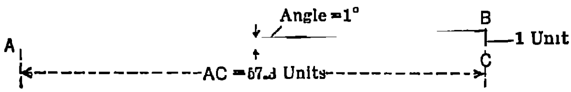


FIG 28 —Relations for 1° Angle

fraction for a grade of 5% must be $\frac{1}{20}$, since a 5% grade means a rise of 5 for a base of 100 or 1 for a base of 20

It is also easily possible to find the slope fraction corresponding to any angle of slope or vice versa. This may be done with sufficient accuracy for many problems, if the slope is not too high, by the relation shown in Fig. 28. In this figure two lines have been drawn, making an angle of 1° and a vertical BC has been drawn perpendicular to the base AC. If BC and AC are measured, it will be found that AC is almost 60 (57.3 to be more exact) times as long as BC. That is the slope ratio is 1 in 57.3 for a slope angle 1°. This relation is very convenient and a student should remember that.

A slope of 1° means a rise of 1 foot in 57.3 feet, or

A slope of 1° means a rise of 1 foot in 688 inches.

Now it is also approximately true as shown in Fig. 29 that a 2° slope will give a rise of 2 units in a base of 57.3 units, a 3° angle a rise of 3, etc. Hence we may write

$$\text{Slope ratio} = \frac{\text{Slope angle in degrees}}{57.3}$$

from which it follows that,

Slope angle in degrees equals 57.3 times the slope ratio.

It is quite obvious that the steeper a slope is the more difficult it will be for horses to pull wagons or artillery up or for troops to charge. The following table, taken from Field

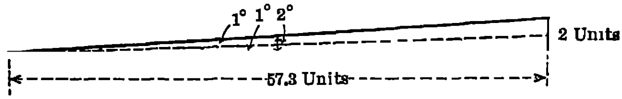


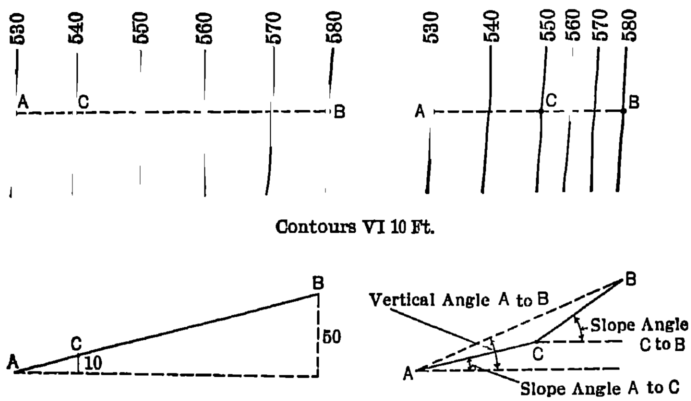
FIG 29 —Relation of Slope Angle and Rise.

Service Regulations, Appendix 7, p. 226, shows the greatest slopes that are practical for certain operations.

Slope			Operation
Degrees	Fraction	Per Cent	
1	$\frac{1}{60}$	2	Maximum for good railroads
3	$\frac{1}{20}$	5	Maximum for first-class roads
5	$\frac{1}{12}$	8	Practical for all arms Somewhat difficult for cavalry to charge descending
6	$\frac{1}{10}$	10	Maximum for cavalry charge in mass ascending Infantry in close order descends with some difficulty.
7	$\frac{1}{8}$	12	Cavalry can descend at a trot
8	$\frac{1}{7}$	14	Not practicable for heavily loaded vehicles
$9\frac{1}{2}$	$\frac{1}{6}$	16	Field Artillery can no longer maneuver
15	$\frac{1}{4}$	25	Maximum up to which all arms can move
$18\frac{1}{2}$	$\frac{1}{3}$	33	Light vehicles can ascend
26	$\frac{1}{2}$	50	Individuals or mules can ascend or descend
45	$\frac{1}{1}$	100	Foot troops can ascend or descend aided by hands

Note that in this table the slope has been expressed as an angle with the approximate equivalents for the ratio and per cent. In studying the table it is also interesting to note that infantry or cavalry can maneuver ascending a steeper slope than they can negotiate descending. The slope figure given for railroads is often exceeded on small lines where grades of as high as 4% are sometimes found, while a large trunk line would not have a grade of over 1% at the most. The slope given for roads is also frequently exceeded and grades as high as 7% will be found on some macadamized roads and country roads will sometimes have grades of 10% and over. No figure is given in this table for motor trucks, but they can

safely negotiate any grade that is suitable for wagons. Indeed the chief difficulty encountered in motor transport in many sections of country is in connection with bridges and culverts. Small plank culverts very often crush through under the heavy wheel loads of trucks. The narrow width of many country roads and the high crown given to the surface also frequently causes a heavily loaded wagon or truck to skid off into the gutter, particularly in wet weather. It might be possible in many cases where the steep grade on a road is short, to double up the teams and take one wagon up at a time. It is almost always advisable, however, to take a longer but easier route



(*a*) One Slope (*b*) Two Slopes

Fig. 30 —Contours and Slopes.

in moving a wagon train to avoid the delay that this procedure occasions.

Slopes may be obtained from contour maps as was indicated in discussing the slope ratio above. This may be done by direct measurement and computation from the map or by using a Map Distance Scale, which is described in Art. 14. To compute the slope the V. I. of the map must be known and the distance on the ground between the contours, which gives the slope, must be scaled from the map by using a reading scale or by measuring it in inches and allowing for the R. F. Thus if the V. I. is 20 feet and two contours are 400 yards apart the slope indicated is 1 in 60 or about 1° or 1.75%.

Note that the steepest portions of a road or slope are the

critical places in considering any operation, hence we first examine the map to find where the contours are most closely spaced. If several contours are evenly spaced a more accurate computation can be made by dividing the sum of the intervals by the distance between the outside contours. Thus in Fig. 30*a* it is more accurate to divide the sum of the intervals A to B, or 50 feet, by the horizontal distance A to B than to divide 10 feet by the horizontal distance A to C. The result should be the same, as the even spacing indicates a uniform slope, but the larger horizontal distance A to B can be scaled with no more error and hence greater accuracy than A to C. Note that this can only be done where the spacing of the contour is uniform. Thus Fig. 30*b*, where the spacing is not uniform, shows not one slope, but two, and if the distance A to B is used the angle obtained is what is known as the vertical angle between A and B and is not the slope angle, as there are two slope angles, that from A to C and that from C to B.

QUESTIONS

1. A slope is $3\frac{1}{2}$ degrees What is the slope fraction? What is the slope in per cent?
2. A construction railroad has a grade of 4% What is the slope angle? The slope fraction?
3. A railroad embankment usually has a slope of 1 on $1\frac{1}{2}$ What is the approximate angle of slope?

Refer to Hunterstown Map

4. Are there any steep slopes on the road from Biglerville (B-5) to Gainer (B-8)? How steep? Answer in grade per cent
5. Are there any steep slopes on the road from Plainview (B-5) to Heidlersburg (A-5)? How steep? Answer in grade fraction
6. What is the steepest slope in degrees on the road from Bridge S H to Hill 712? (B-6) Answer in slope angle.
7. Determine the per cent grade of the steepest slope on the portion of Chestnut Hill shown on this map (A-6).

ART. 14. SLOPES—(*Continued*)

It is the practice to give at the bottom of the U. S. Army War Game maps, in addition to the usual reading scale, a scale showing what are called map distances, or distances between consecutive contours on the map for various slopes. A scale of this kind is shown in Fig 31 and is usually referred

to as a M. D. (map distance) scale, although **slope scale** is a better term. The slope scale furnishes a very rapid and convenient method of getting the slope between any two consecutive contours on the map. Thus if the distance between two consecutive contours is laid off on a strip of paper and when compared with scale just equals the distance from A to B, then the slope is $\frac{1}{2}°$, if it equals BC the slope is 1°, etc. Or a copy of the scale may be made on a piece of paper and this copy applied directly to the map, the slope being found by moving the scale until two divisions on it coincide with the two consecutive contours on the map the slope between which is desired. In many cases no divisions on the scale will exactly fit the contours. For example, two contours may be closer together than the division from A to B in Fig. 31, but not as close as B to C. This means that the slope is between $\frac{1}{2}$ and 1°.

It will be noticed that the divisions on this scale bear a very simple relation to each other. Thus the length AB is

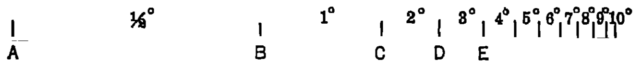


Fig 31 —Slope Scale

twice the length BC, CD is half BC, DE is a third of BC, etc. When we remember that a slope of $\frac{1}{2}°$ becomes (approximately) a slope of 1° if the rise is kept the same and the base is reduced to one-half the reason for this relationship is clear. It will also be true that if the distance between the outer two of four consecutive evenly spaced contours just coincides with the distance between the 1° divisions (BC in Fig 31) then the slope is 3 times 1° or 3°. This furnishes a method of scaling slopes so that a scale with only even divisions like those shown in Fig. 31 may be used to get practically any slope.

Most maps do not have a slope scale printed on them, and if we desire to measure many slopes it is advisable to make a slope scale. The construction of a slope scale is quite simple and is best illustrated by an example.

Suppose a slope scale is required for a map drawn with a R. F. of 1 . 21,120 and having contours with a V. I of 20 feet. We compute the distance required on the map between

two consecutive contours for a slope of 1° and then divide this value to obtain the distances for other slopes as indicated above. Thus if the V. I. is 20 feet the slope of the ground between two consecutive contours will be 1° if these contours are 20 times 57.3 (see Art. 13) or 1146 feet apart, that is if the rise is 20 in 1146 or 1 in 57.3. Now 1146 feet is 13,752 inches and, if the R. F. is 1: 21,120, this distance would be shown on the map as 13,752÷21,120 or 0.65 of an inch. Hence the map distance for 1° is 0.65 inch and we lay off BC in Fig. 32=0.65 inch using for this purpose an engineer's, or decimal scale (see Fig. 24). The scale is then completed by laying

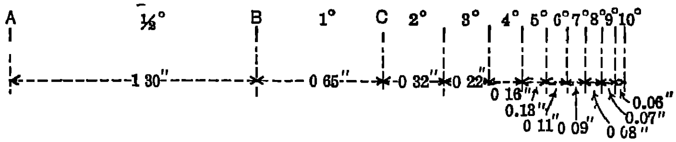


FIG 32 —Construction of Slope Scale

off AB just twice BC, or 1.30 inches, CD half as long as BC or 0.37 inch, etc , as illustrated in the figure.

We may write out the steps in this computation in the form of an equation as follows:

$$MD = \frac{57.3 \text{ times V. I in feet times 12 times R. F.}}{\text{Angle of slope in degrees}}$$

where MD stands for the distance on the map in inches between two consecutive contours for any angle of slope.

It will be noted in connection with the U. S. Army maps that the V. I. and R. F. are so related that one slope scale will serve for all of these maps. For example, if the scale of the map is 12 inches=1 mile, the V. I. used is 5 feet, if it is 6 inches =1 mile, the V. I. used is twice as large, or 10 feet, etc., hence the distance on either of these maps for a certain slope will be the same These R. F.'s and V. I 's are therefore called normal scales. The fact that the spacing of the contours always shows the same slopes means that the ability to picture in the mind the size and slopes of hills from one of these maps holds also for the others, whereas with the usual maps of

different scale and V. I. each map must be studied and visualized by itself.

QUESTIONS

1. The scale for some of the English Trench Maps used in France was 1:20,000 The contour interval was 10 meters Construct a slope scale for slopes of ½, ¾, 1, 2, 3, 4, and 5 degrees

Note. 1 Meter equals 3 28 feet or about 39⅓ inches

Using the Hunterstown sheet, the M.D or slope scale printed thereon and the table of practical slopes given in Art 13, answer the following questions:

2. Could wagons go straight up Chestnut Hill from the south? How steep is the slope?
3. Could cavalry charge freely east of Table Rock Station? (C-8)
4. Could artillery move on every slope on this map? If not, tell where not
5. Could infantry move on every slope on this map? Could it charge? If not, tell where not.

ART. 15. INTERVISIBILITY OF POINTS

The problem of determining whether one point on the ground is visible from another point, that is, whether or not

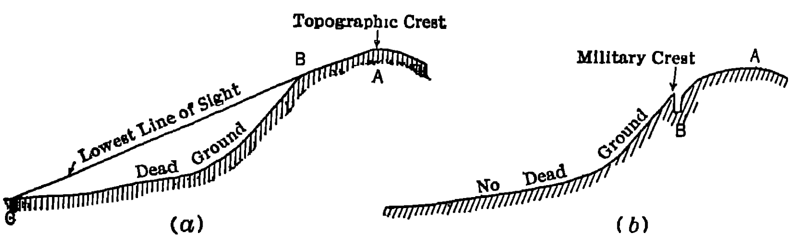


FIG. 33—Topographic and Military Crests

our "line of sight" is cut off by some intervening hill, can be readily determined from a contour map and is of great importance in military operations. For example, in selecting signal stations, in determining whether a certain road is visible from any enemy position, etc. The method used in working out these questions also leads to the problem of visibility of areas, discussed in the next article, is basic in making a landscape sketch from a map, and is frequently used as an aid in the recognition of objects in the field from a map.

One of the simplest problems in visibility is illustrated in Fig. 33. An observer at the topographic crest of the hill,

shown in profile in Figure *a*, would not be able to see to the bottom of the hill, as his line of sight would be cut off by the brow of the hill at B. All the ground between B and C is therefore out of sight and is "dead ground." In locating a trench on a hill like this, it would be located as shown in Fig 33*b* at the "military crest," so that an attacking party would be in full view from the trench and could not take advantage of the cover offered by dead ground, as would occur if the trench was placed at the topographic crest. Note the characteristic contour spacing for a hill of this kind shown in Fig. 34*a*. It is obvious that the trench must follow closely the line of the 550 contour. When the contours are spaced as in Fig. 34*b* the topographic and military crest coincide.

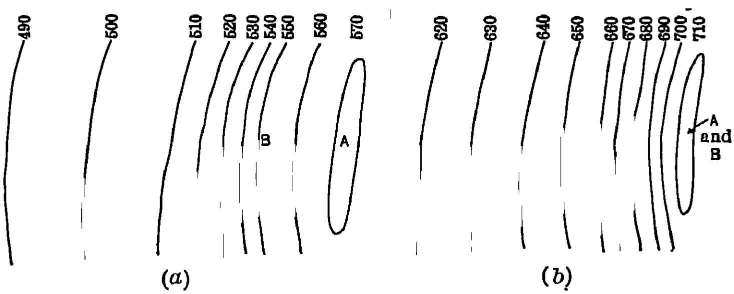


FIG 34—Location of Crest as shown by Contours

The problem of locating the military crest of a ridge does not, therefore, require drawing a profile and it can be easily traced on a contour map, provided the student understands contours and is able to picture in his mind the profile of a slope by studying the contours.

In connection with the problem of intervisibility of two points (a low point A and higher point B) when there is an intervening hill or obstacle in the way it is clear,

1. That we can see from A to B if the height, or elevation, of C is not greater than that of A, the lower of the two points.

2. If C is as high or higher than B then A and B are not intervisible.

3. If C is intermediate in height between A and B further study is necessary to answer the question

For example, we are standing at the corner of the roads

near D. Wirt's farm (C-6) on the Hunterstown sheet. Can we see the top of Chestnut Hill (A-6)? Our elevation at Wirt's is 552 plus our height, say 558 feet. If there is no hill between Wirt's and Chestnut Hill higher than 558 we know that we can see to the top of Chestnut Hill, as it is higher than 558 (shown as 931). Upon examining the map we; find that there is a hill between having an elevation of 712, hence further study is necessary to answer the question.

Fig. 35 shows a profile drawn on the line from Wirt's to Chestnut Hill. If we draw a line of sight on the profile from A just touching the top of C we find that it is high above B, hence the obstacle C effectively blocks out our view of Chestnut Hill. It is immediately obvious that it was unnecessary

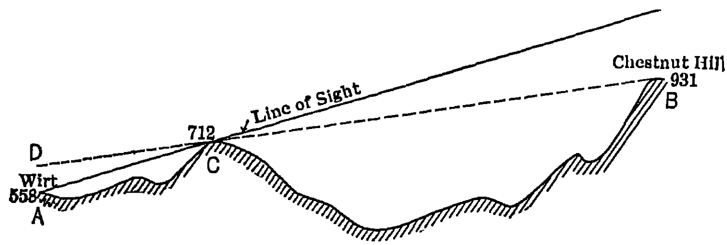


FIG. 35 —Intervisibility.

for us to plot a complete profile to answer this question. All we need to plot are A, B, and C.

Instead of answering the problem by a graphical solution as above we can easily work it out mathematically. Thus we find that the distance from Wirt's (A) to Hill 712 (C) is one mile, while that from Wirt's to Chestnut Hill is $3\frac{1}{2}$ miles on the map. Now a line of sight from Wirt's just passing over Hill 712 will rise $712-558$ or 154 feet, or a rise of 154 feet in one mile. Hence at a distance of $3\frac{1}{2}$ miles the line of sight will rise in proportion $154 \times 3\frac{1}{2} \div 1$, or 540 feet, and its elevation will be $558+540$, or 1098 feet, which is higher than Chestnut Hill (931) and the hill is therefore invisible. This method is illustrated in Fig 36. Note that the distances A to C and A to B need not be scaled in miles, but can be measured in any convenient unit. Indeed this problem can be solved mentally with sufficient accuracy to answer the question.

It is obvious that Chestnut Hill would have been visible if the line of sight at B had been 931 feet or lower. Another problem which is solved in a similar manner is to determine the height necessary for a tower at Wirt's in order that we may see Chestnut Hill. Graphically we simply draw a line of sight back from B just touching C and find that it comes

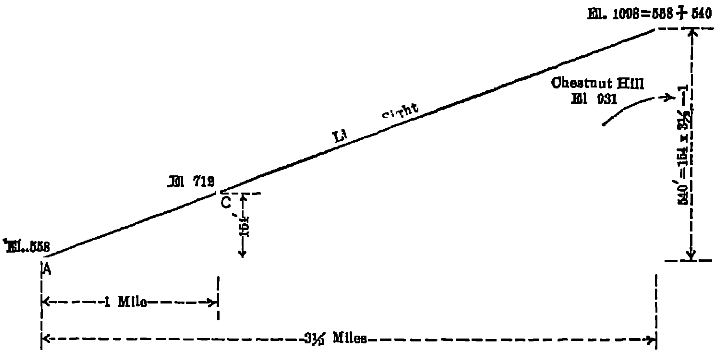


Fig 36 —Intervisibility Computation

at D about 60 or 70 feet above A, giving the required height as shown by the dotted line in Fig. 35. Mathematically, we know that this line of sight must have a slope of $931-712$, or 219 feet in $2\frac{1}{2}$ miles (the distance from Hill 712 to Chestnut Hill), hence between Hill 712 and Wirt's it will drop $219 \times 1 \div 2\frac{1}{2}$, or 88 feet and its elevation at Wirt's would be

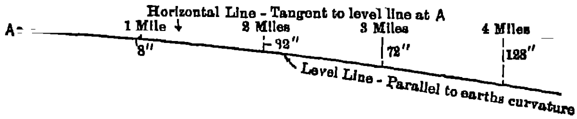


Fig 37 —Error Due to Curvature of the Earth

$712-88$, or 624 feet. Hence the tower at Wirt's would have to be at least $624-558$, or 66 feet high.

Note that the map used in the above problem shows trees and the orchard on the north slope of Hill 712 may interfere with our view. Also the trees on Chestnut Hill might interfere with a view from there toward Wirt's. On maps where

trees are not shown an allowance of 40 or 50 feet or more would have to be made for them.

It is also true that the curvature of the earth would amount to enough in long sights to make allowance for it necessary. This is illustrated in Fig. 37 where AB is a horizontal line at A, that is, it is tangent to the earth's surface at A, and AC is a level line, that is, is parallel to the earth's surface, and it is from such a line that heights shown on maps are measured. Now the difference between these two lines is 8 inches in a distance of one mile and increases as the square of the distance (approximately). Hence an object four miles away due to curvature would appear to be $10\frac{2}{3}$ feet $(=8\times4\times4\div12)$ lower than it is.

QUESTIONS

1. Could you see Hunterstown (D-5) from top of hill 574 (C-6)?
2. Could the enemy see you at Herman (C-7) from Biglerville (B-8)?
3. Could they see you at Goodintent S.H.? (D-7.)
4. You have been on lookout for three hours on hill 712 (B-6) A farmer tells you that he just came from Center Mills (A-7) to Bridge S. H. (B-6) with a hostile regiment. Is it true?
5. You are in Hunterstown (D-5) for a half-hour stop and expect enemy from west. Where do you put lookouts?
6. You are marching southwest from Plainview (B-5). Where do you send patrols if enemy is expected from west?
7. Do you send a separate patrol to each hill?
8. Enemy has artillery at Biglerville (B-8) and holds line of Conewago. You are told to take a company from Goldenville (D-8) to Texas (C-8). Describe route?
9. You are at cross-road 600 (B-7). You are ordered to go in daylight to Center Mills (A-7) without being seen. Describe route?

ART. 16. VISIBILITY OF AREAS

Fig. 38 is identical with Fig. 13 except that a portion of the upper part of the map has been shaded. This shaded portion is ground that is not visible to an observer stationed at the point A, that is, it is dead ground. It requires time and patience to work out on a map and show in this way the areas visible or not visible from a given point, but such a problem is an excellent study in contours and the visualization of the

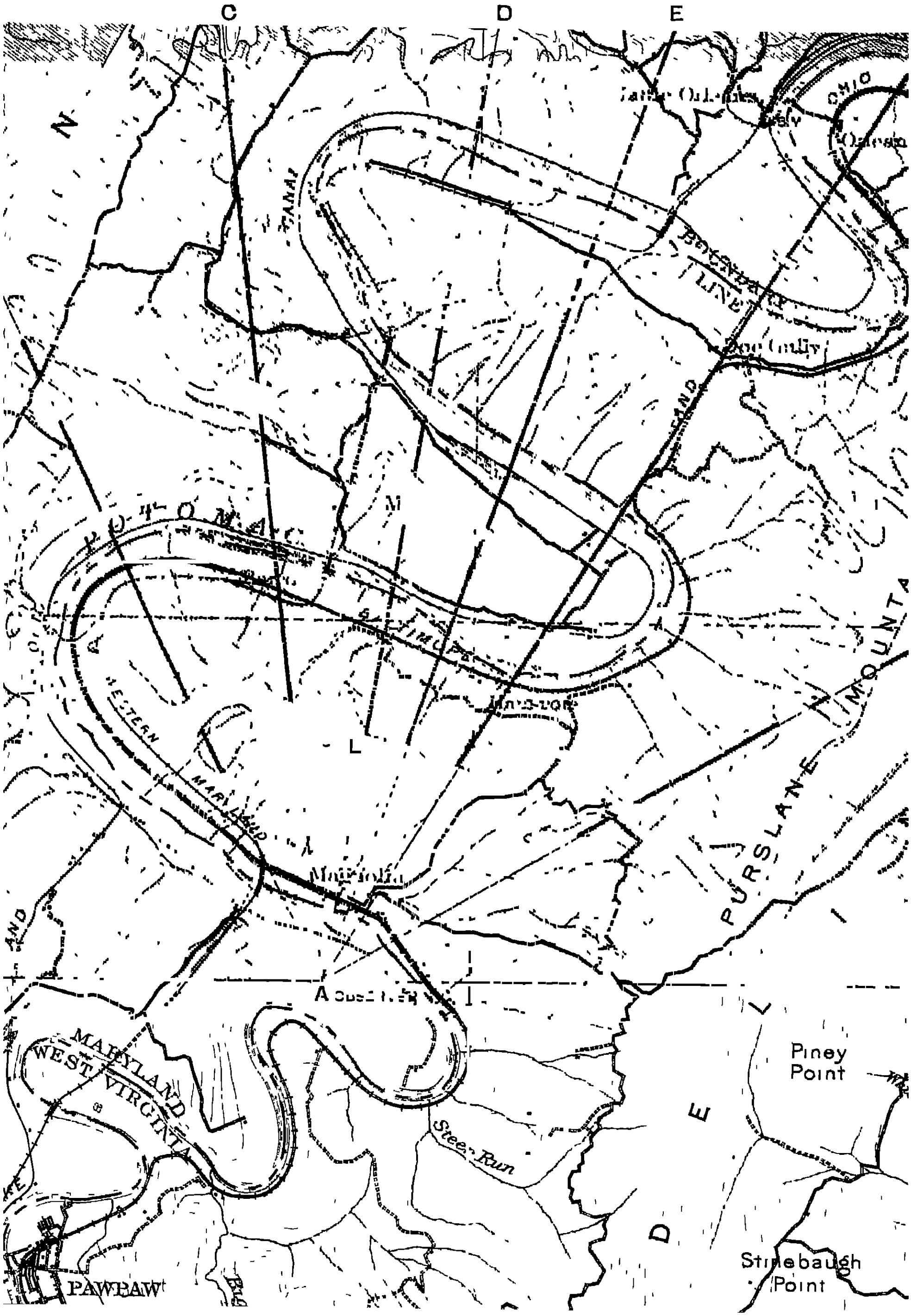


FIG 38 SHOWING AREA VISIBLE FROM POINT OF OBSERVATION AT A

relief. The result is of value in military work in planning attacks or troop movements, so as to take advantage of cover and in such work as locating observation stations, etc. In artillery work it is desirable to work out on a map in this way the dead ground in front of an artillery position and place the various batteries so as to effectively cover the entire area. In the case of artillery fire it is necessary to allow for the curving trajectory of the projectile and large areas that are not visible to the eye can of course be reached by the guns.

The problem of working out the visible area is simply the application of the principles of Art. 15 to an area rather than

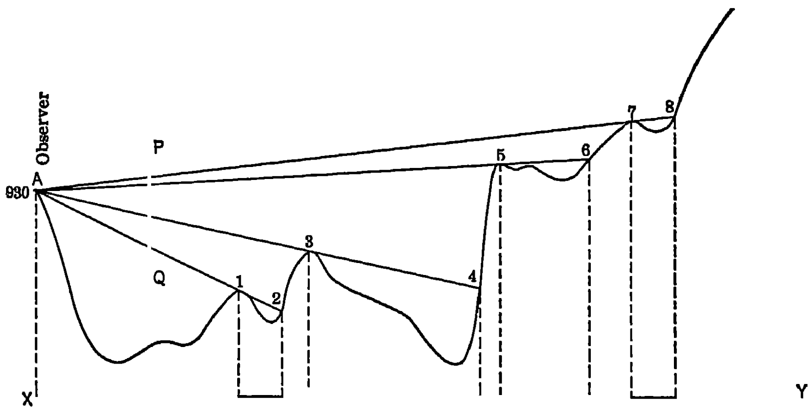


FIG 39 —Profile showing Lines of Visibility.

one line. Thus from the map (Fig. 38) we can construct a profile on one of the radiating lines, such as AB, which have been drawn from the position of the observer at A. Fig 39 shows this profile. From the observation point A, which is at elevation 930, draw the lines of sight just over the intervening hills 1, 3, 5, and 7. It is obvious that the ground between the points 1 and 2, 3 and 4, 5 and 6, and 7 and 8, is invisible, and this has been indicated by drawing the line XY at the bottom of the profile and marking the invisible portions with a heavy line. This marking is now transferred back to the map, Fig. 38, giving the line AB with invisible portions indicated by heavy ruling. Profiles are constructed and the

invisible portions of the other radiating lines AC, AD, AE, etc., are shown on the map. Indeed it would be advisable to work out even more lines than those shown. It is not always necessary to construct profiles in order to work out the visible portions, as this can be done quite easily mathematically. For example, on the line AD it is obvious that our line of sight will be cut off by the crest of the hill at L, just across the Potomac from the observer. The next hill which may, or may not, be visible is about an equal distance from the first hill across the next bend in the river at M. Now the crest of the first hill (L) is at about elevation 830, hence the line of sight from the observer passing just over this hill will drop from 930 to 830 or 100 feet in this distance, and in the approximately equal distance to the second hill (M) will drop about 100 more and hence will be at about 830 − 100 or 730 at M. Now this hill rises to over 820 feet, hence it will be visible from elevation 730 to the crest as shown. This same method can be followed for the next hill, N, in which case the line of sight is controlled by the elevation of the observer (930) and the elevation of the crest of the hill, M.

Having indicated the visible and invisible portions of the ground on a number of these selected lines radiating from the observer, it is next necessary to connect up by eye the corresponding points on the different lines and thus outline the boundaries of the dead ground. This requires considerable thought and skill, and the following points will be helpful.

1. Hillsides facing toward the observer, and not cut off entirely from view by an intervening hill or ridge, will be visible from their crest for a certain distance down the side, the amount of which is determined by the height of the intervening hill. Hence

2. The crest of ridges form one of the lines of division between visible areas and dead ground. Note in Fig 38 that the ridge line of the first hill, L, which can be easily drawn from the contours, forms the boundary of the dead ground, and that the upper boundaries of practically all the visible portions north of this hill are ridge lines

3. The lower boundary of the visible area will run along the sloping hillside facing the observer. Its shape will depend

on the form of the obstructing ridge nearer the observer, which prevents him from seeing to the bottom of the valley. If this ridge is practically level and not far above or below the observer, the lower boundary of the visible area will follow approximately a contour line along the farther hillside.

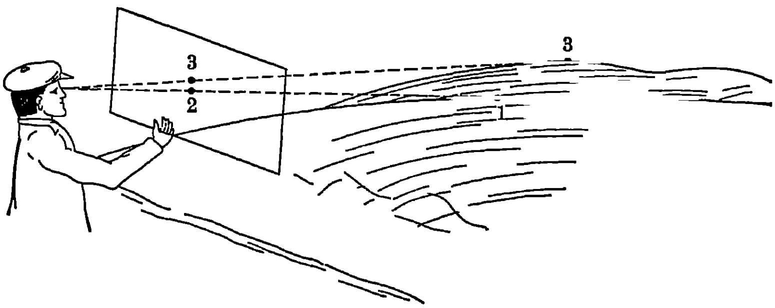


Fig 40 —Picture Plane.

If the intervening hill is irregular in crest outline the boundary line on the side of the hill in question will show similar irregularities that can be completely determined only by drawing many radiating lines from the observer's station.

In choosing where to put the radiating lines remember—

Fig 41 —Control Points for Sketch

(*a*) That a hill hides the country behind it, while

(*b*) A sag or a gap permits us to see farther down on the next slope behind it. Draw the radiating lines so that some of them pass over the tops of hills and some through gaps, or sags.

(*c*) Draw these lines only at critical or guiding places. A great number is not necessary in most cases, as only the general outline of the dead ground is required and irregular outlines, such as those on the mountain ridges on the sides of Fig. 38, are unimportant and can be put in by eye.

The principles used in this problem of visible area may be used to make a landscape sketch showing the view of the hills and ridges from the point of observation. Thus if we held a transparent vertical plane in front of our eye, as indicated in Fig. 40, the lines of sight to the hilltops 1 and 3 would intersect this picture plane at 2 and 4. Now if we imagine a plane of this kind, the edge of which is shown as

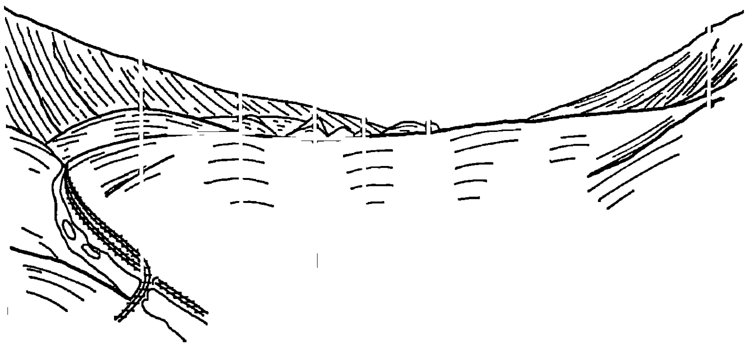


FIG 42 —Landscape Sketch Made from Map

PQ in Fig. 39, the points where the lines of sight A1, A3, A5, etc., cut this may be marked. By doing this for each of the radiating lines we secure the points plotted on Fig. 41 and these can then be connected up by eye giving the view shown in Fig. 42. This view will not be a "natural picture," as the vertical scale used for the profile was much exaggerated, but it does give a clear idea of the view the observer would have if he stood on the hill at A in Fig. 38 and looked north. This illustration serves to show what complete data a topographic map gives us in regard to the country represented—we can make an exact model of the country from it and even draw pictures of the views we would see from different points and without making the model.

PROBLEM

1. Assume the point of observation is on the hill, about $1\frac{1}{2}$ miles west of A in Fig. 38, having an elevation of 950 feet (estimated, highest contour is 940). Draw six or seven radiating lines, plot profiles and plot out area visible. (Map shown in Fig. 13 may be used for this problem.)

CHAPTER III

USE OF TOPOGRAPHIC MAPS IN THE FIELD

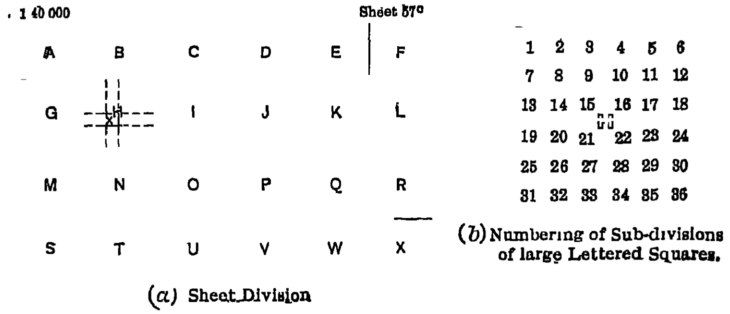
Art. 17. Coordinate and Grid Systems

It is especially necessary in military work to have some simple system of referring to any point on a map and identifying this point on the ground or the reverse. It is usually very easy to describe a point in a general way, particularly if it is near a town. For example, we may speak of the "orchard $\frac{1}{4}$ mile south of Table Rock" on the Hunterstown sheet. Furthermore, we have used the number and letter system which is used in atlases and is given on this sheet. We can thus add to the above description C-7 which assists us in locating Table Rock. A description of this kind is clumsy, however, and does not permit us to describe points in detail, except by long descriptions and reference to more prominent objects. Various other, more definite, systems of reference have been devised and two of these, used by the English and French, respectively, on their war maps of the Western Front, will be described.

The English system was a combination of lettered squares with coordinates for the final designation. It is known as a "grid system." The larger maps published by the English Survey Division, Dept. of Militia and Defense, were drawn to a scale of 1 : 40,000 and were published in sheets with an index number and letter. Each of these large sheets, one of which might be described as sheet *57c*, for example, was divided into large squares or rectangles, each of which was designated by a letter, A, B, C, etc., as indicated in Fig. 43*a*. All of these lettered squares were divided into 30 to 36 smaller squares, as shown for Square H in Fig. 43*a*, 1000 yards on a side, numbered in much the same way as the sections are

numbered in the scheme of division of the U. S. Public Lands, and shown for Square H in Fig. 43*b*.

With the "grid" printed over the map it was possible to describe a point as being on Sheet 57*c*, large square H, small square 20, for example. Furthermore, each of the small numbered squares was again divided into four quarters lettered *a*, *b*, *c*, and *d* as shown in Fig. 43*c*, which is supposed to represent a large scale drawing of Square H 20 of Fig. 43b. A



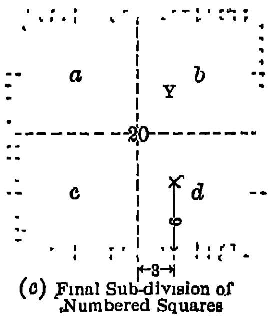


FIG. 43 —The English Grid System

point could now be described as H 20*d*, giving its location within 250 yards. This, however, was not close enough and for a final description within the small lettered squares, *a*, *b*, *c*, and *d*, the coordinate system was used. That is, the sides of the squares *a*, *b*, *c*, and *d* were supposed to each be divided into ten equal parts and to be numbered from the *lower left-hand corner*. The point X in Fig. 43*c* would then be described by stating first the number of these divisions to the right of

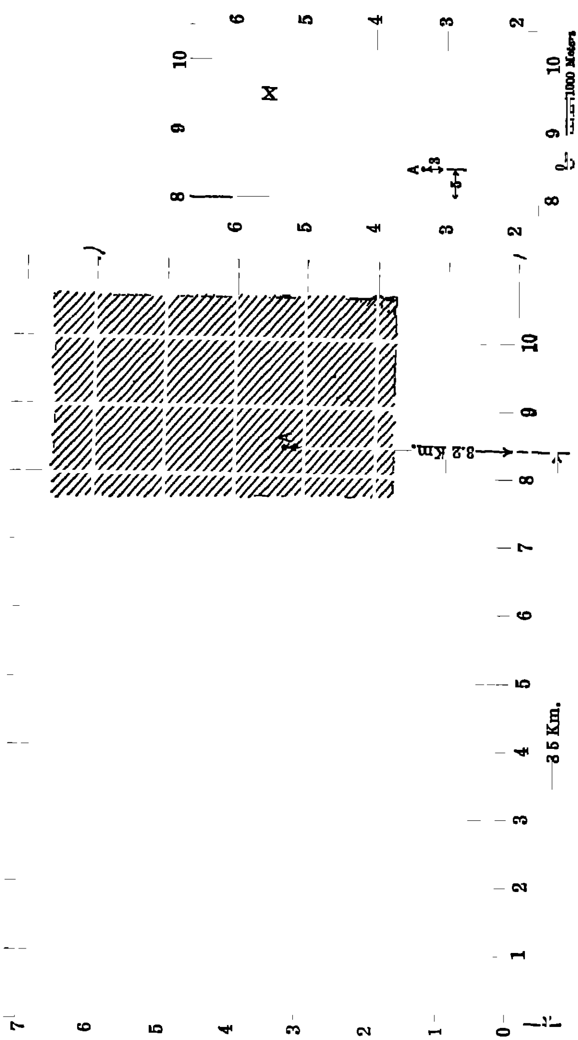
the zero corner and then the number up or 3, 6. This system permits a description to be written within $\frac{1}{10}$ of 250 or 25 yards, and when still more accuracy was required the coordinates were based on the division of the sides of the small squares into 100 instead of ten parts. The complete description of the point X would read Sheet 57 *c*, H 20 *d* 36. This grid system was printed at the proper scale on all the maps issued so that a description given from one map would be the same for all. Thus on the 1: 20,000 maps the size of the squares was doubled, so that the larger squares would still be 1000 yards on a side as before and similarly for the 1: 10,000 scale.

The French system was a coordinate scheme pure and simple and no lettered squares were used. It is a better reference for artillery work, as distances may be computed directly from the coordinates, whereas in the English system it is necessary to change the data, as can easily be done, into coordinates. The English lettered and numbered squares, on the other hand, have the advantage of being easily understood and hence preferable for infantry where the men are not familiar with coordinates and liable to make mistakes.

Fig. 44 shows the French system. Lines were drawn on the maps 1000 meters, or a kilometer ($\frac{5}{8}$ of a mile) apart from the zero point, or origin, at 0. These divided the area into squares the dividing lines of which are numbered to the right and upward from the origin, thus giving their distances in kilometers from the origin. The description of a point is given by two series of figures, for example, the point A is described as 85.33. This means that the A is 85 hectometers (8.5 kilometers) to the right of the origin and 33 hectometers above it as shown by the dimensioned lines on Fig 44*a*. Note that the distance to the right (known as the abcissa) is always given first with the distance up (ordinate) following.

If a single sheet showed a map of the shaded area of Fig. 44*a* the kilometer lines would be shown as illustrated in Fig. 44*b*. Remembering that the numbers on the lines are their distances in kilometers from the origin and scaling the distances 5 and 3 to the nearest 100 meters over and up from the corner 8.3, by using the reading scale given at the bottom of the map we obtain the hectometric coordinates of A 85.33

as given above. This locates the point A within a hectometer or about 100 yards. If this is not sufficiently acccurate the dekametric coordinates can be given by scaling the distances from the corner 8.3 to the nearest 10 meters. These might be



(a) General scheme.

(b) Kilometer grid as shown on a map sheet.

FIG. 44.—The French Coordinate System of Reference.

52 and 34 and the dekametric coordinates would then be 852.324.

It is clear from the above that points shown on maps may be accurately described by either of these map reference

systems. The next article deals with the use of a map in the field, the location of points on the ground from maps and the reverse operation of locating points on a map from the ground.

QUESTIONS

1. Describe the location of the fork in a road indicated by the letter Y in Fig 43*c* Assume that this figure represents a sub-division of square 20 of large square P of Fig. 43*a*
2. Mark on Fig 43*a* the approximate position of the point mentioned in (1)
3. Describe the location of the cross-roads indicated by the letter X in Fig. 44*b* and mark its location on Fig. 44*a*

ART. 18. USE OF MAPS IN THE FIELD

The ability to use a map intelligently in the field and obtain from it the required information is the main aim and object of the study of map reading. Real ability in this direction can only come as the result of practice in actually using maps in the field, solving the problems of location and identification which are met, and comparing the actual objects with their conventional representations on the map. Some of the problems which may arise in connection with using maps in this way are briefly outlined in the following paragraphs.

The first step when using a map in the field is to orient it as has been described in Art. 9. The object is to so turn the map that the direction of north on the map coincides with the direction of north on the ground and object shown on the map will appear in the same direction as the actual objects on the ground.

The second step is to find on the map the position you occupy. This is not always as easy as it would seem and to be able to pick out a certain point on the map and say "I am now at this point" often requires considerable careful study It is generally possible to locate the point we have come from and trace out our route on the map and in this way find out our present location. Special attention should always be given to keeping in mind the various landmarks that are passed during a trip. Certain buildings such as churches or schools which are shown by special conventional signs should be remembered. When the question of which turn to take in

a road comes up, for example, and the map is consulted we first must find out where we are on the map, and it helps a lot in answering this question to remember that we passed a church about a mile back, or crossed a stream, etc. Even with these observations to aid us mistakes are often made, and no final location should be selected until the view in all directions from the actual point and the point selected on the map have been compared. There is a hill to the northwest, for example, with a lower hill to the east, etc., and these observations check with the contour indications on the map. Constant watchfulness and attention to details is required in many cases to locate one's position on a map, and it is well to remember that it is ordinarily not very difficult to find two or more places on a map that will fit a general description with fair accuracy.

Under abnormal conditions this problem of location becomes very difficult indeed. For example, it happened in a number of cases in the war zone in France that parties fully equipped with large scale maps walked right through towns several times without being able to find them. This was due to the fact that the map showed a landmark that had been absolutely wiped out. It was necessary to put up signs in the field to assist in identification and a town was identified by a sign or the map reference such as A 20 c 68, of a point in the field was given by a sign to assist in location.

Having oriented the map and found our location on it the next step is to identify other points and objects. In fact this, as indicated above, is generally a necessary preliminary to discovering our own location. In this connection direction is important (see Art. 9) and it is also desirable to be able to judge distances with a fair degree of accuracy. Again actual practice in the field in estimating distances to various objects and comparing them with the true distances scaled from a map, is the best practice. Attention to the clearness and relative size of such objects as trees, houses, telegraph poles, etc., helps in judging distances.

Being able to judge the distance and knowing the direction of an object it can be quickly recognized on the map or in the field. In mountainous country the problem of visi-

bility (see Art. 15) is often of value in proving a certain location by noting whether objects in the field should or should not be visible according to the map. This is particularly valuable in identifying distant mountain peaks.

Where the exact location of the observer is important and no object shown on the map is near by, the following method can be used. Some object shown on the map and visible

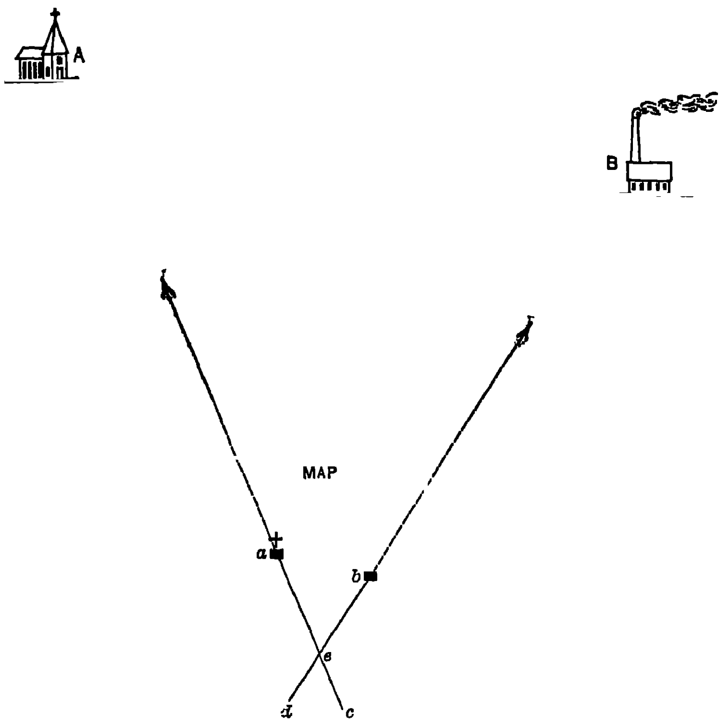


FIG 45.—Resection Method.

in the field is selected and the observer paces, or measures with a tape, the distance to it and notes the direction with a compass. He then starts at this object as shown on the map and "plots" back the distance with the reading scale in the proper direction, thus locating the point in question. Another method, known as "resection" is illustrated in Fig. 45. The map is placed in a horizontal position, preferably on a drawing board, and is correctly oriented. Two objects

A and B visible in the field and shown on the map as *a* and *b* are selected. A ruler is placed on the map so that its edge passes through one of the objects, say *a*, and the ruler is turned so that it also points in the direction of this object in the field, A. An indefinite line is drawn for this position, *ac*, and the same procedure is followed for *b* and B, giving the line *bd*. The intersection of these lines at *e* is the location of the observer. Similar methods can be used to plot on the map the location of objects in the field and thus recognize them or complete the map if they are not shown. Such work, however, is properly part of the work of mapping and is treated in Part II.

QUESTIONS

See Hunterstown Sheet.

1. You have been marching southwest from Hunterstown (D-5) for about three-quarters of an hour and have halted just beyond a schoolhouse near a small orchard to the east of the road Find location on map.
2. Draw a sketch to show the plan or map of a room. Orient the sketch and find your position in the room by resection from two corners.

PART II

SKETCH MAPPING

INTRODUCTION

Army officers must not only understand topographic maps, but must also be able to make simple military maps, the latter work being particularly necessary when operations are being carried on in a country where no large scale maps are available. The army engineers of course do most of this work, and in the operations on the Western Front in the Great War the maps were not only made but were printed in colors, with special equipment, by the engineer force in the field. Numerous minor sketches showing details of various positions, etc., were made, however, by infantry officers, and the methods used in simple sketch board work are therefore of importance to infantry officers. The principles involved are also fundamental in the preparation of the "directing plan" and other features of "orientation" in artillery work.

In civil life the ability to make a sketch map with simple instruments is of great importance in all kinds of prospecting work, particularly in geological or mining examinations.

The methods used in sketch mapping are various and differ for different purposes. The following discussion of the subject does not attempt to give all methods or instruments used. Indeed only the simple army sketch case, which can be easily and cheaply secured,* is described, and its use in sketching developed. Other instruments and the methods used in extensive topographic work, such as the maps published by the different governments, engineering surveys, etc., are dis-

* See Appendix 2.

cussed in books on surveying,* and a much more complete course of study and field training is necessary.

It has sometimes been said that topographers are born, not made. It is undoubtedly true that some men possess much greater ability than others in making maps and sketches that represent faithfully the country mapped. Sketch mapping in particular has often to be done under adverse conditions and time is not always available to take many measurements, so that a skilful topographical surveyor can do better and speedier work than a man who has not had this training. Practice and experience are the important elements to success in sketch mapping and proficiency can only be obtained by actual field experince.

Before discussing methods of mapping it is necessary for a student to have practice in topographic drawing, and this feature of the work is therefore discussed first.

* See for example Wilson's "Topographic Surveying."

CHAPTER I

TOPOGRAPHIC DRAFTING

Art. 19. Freehand Lettering

A large number of books* have been published on this subject and it will only be possible here to give a few notes on the most important points.

Lettering is used on maps and in engineering work because it gives the desired information more clearly and compactly than writing. Contrary to the ideas of most students the ability to do very respectable freehand lettering can be quite

Fig 46.—Inclined Lettering.

easily cultivated and requires simply practice and attention to a few simple rules. Once acquired, freehand lettering will be found to be extremely useful for many kinds of work.

One form of letter should always be followed and the best is the simple style shown in Fig. 46. The letters may be made in two ways—either vertical or inclined. These are equally good, and it is probably easier to learn the type which conforms to the slope of one's handwriting.

Parallel horizontal lines, known as guide lines, should always be drawn to keep the lettering on line and assist the eye in keeping a uniform height of letter. In starting it is desirable to make the letters large, say one-quarter of an inch high, and practice the capitals first because these are easier

* See particularly Reinhardt's "Freehand Lettering"

than the small letters, as they require fewer curved lines. Pay particular attention to the form of the letters, carefully following the simple shapes, proportions, etc., of Fig. 46 and omitting all flourishes, tails and other additions that beginners frequently add. Remember that good lettering cannot be done by a quick jerky motion of the hand or like handwriting. *A slow uniform motion with even pressure* on the pencil or pen must be used, and it is desirable, particularly to avoid blots in pen work, to follow the order and direction of the strokes shown by the numbered arrows in Fig. 47. Note also that wide letters are not desirable, as they take more room; rather make the letters high and narrow.

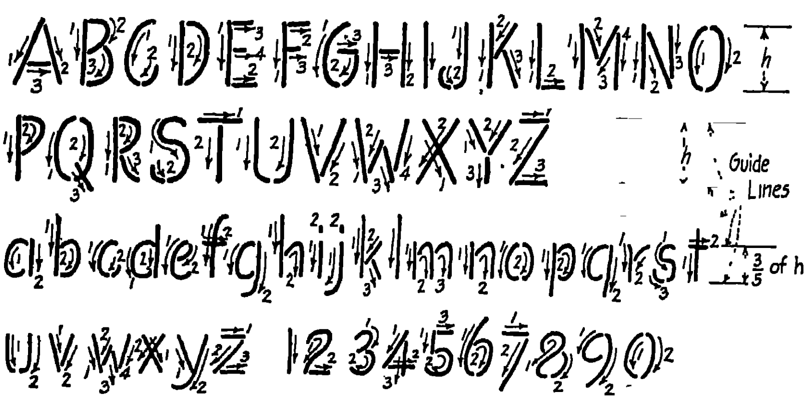


Fig. 47.—Sequence of Strokes, Vertical Lettering

Students are often inclined to make the small letters too small in proportion to the capitals. After practicing with the capitals additional guide lines for the small letters should be drawn three-fifths the distance apart of those used for capitals. Here again a number of practice sheets should be made and care given to obtain the simple form and proportions with a uniform pressure on the pencil.

The next step should be the combination of letters into words. The size of the letters may now be reduced to that which will actually be used in notes and data on maps. This should seldom be less than one-tenth of an inch for the small letters. "Microscopic" work should be avoided In bringing letters together to form words special attention must be

given to the spacing between the letters. This is one of the hardest features of lettering, as the spacing is not uniform for all letters but must be varied not only for each letter, but also depending on the form of the adjacent letters. Spacing cannot be done by rule, but must be left to the eye. In general, keep the letters as close together as possible, in particular those adjacent to the letters A, V and Y, the round letters C, G, O and Q; also the letter before a J or following a P or L. The object is to make each word look like a single unit without any breaks or unevenness in appearance.

EXERCISES

The following exercises should be repeated several times and lettering should be practiced on scraps of paper during odd moments:

1. Draw guide lines and letter a few alphabets of capital letters one-half inch high. After each attempt compare it for form, etc., with Fig. 46 and correct the errors in the next.
2. Do the same for the small letters except that they should be three-tenths of an inch high.
3. Do the same for numerals, making them the same height as the capitals.
4. Draw a series of guide lines for capitals about two-tenths of an inch high with small letters a little over one-tenth high. Select a paragraph from the text and do it in freehand lettering.
5. Using guide lines as in (4) and giving special attention to spacing do the following in freehand lettering "The attacking aeroplanes were flying very quickly." Note especially that most of these letters must be kept close together and that the A can be drawn partly under the head of the T, etc.

ART. 20. TOPOGRAPHIC DRAFTING

One of the first steps in topographic mapping is to select a series of conventional signs. For formal publications, such as governmental maps, quite an elaborate series of signs in colors is appropriate, while for rapid sketch mapping in the field the signs used must be simple, easily made and suitable for pencil work. The former type has been discussed in Art. 3, Part I. Fig. 48 shows a very simple set of signs, which are practically those used on the war game maps prepared by the army schools at Fort Leavenworth. They are well adapted for field sketching with the sketch case.

The student should review Art. 3 on conventional signs, particularly as regards the number of signs and the corresponding detail in its relation to the scale of the map Additional signs to supplement Fig. 48 should be taken from those adopted by the U. S. Geographic Board, which are practically those of the U. S. G. S.

Note that the size of each conventional sign depends on

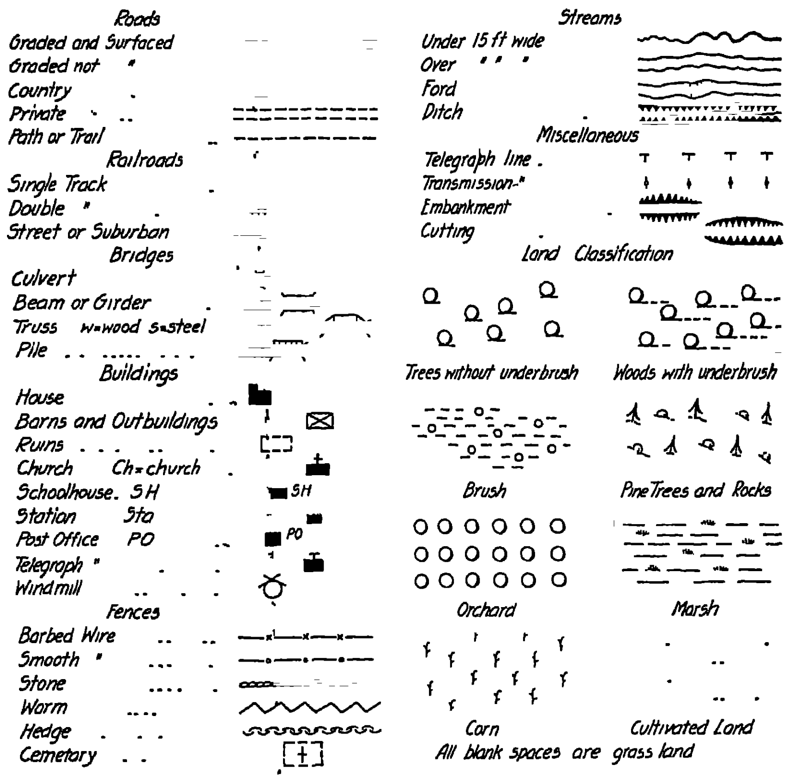


FIG 48 —Conventional Signs for Sketch Mapping

the scale used and at the same time seldom represents to scale the object it symbolizes. Buildings are shown correct in size and shape. The two lines representing the sides of a road, however, are not shown their proper distance apart except on very large scale maps—it would be impossible to draw two distinct lines, say twenty feet apart, on a map having a scale of one inch equals one mile, for example, while for a scale

of one inch equalling one hundred feet this can be, and is, done.

Trees are never shown to scale and when in clumps or groups only the group is indicated. The exact number, that is individual trees, are shown only for isolated trees. Note the distinction between woods with and without underbrush as indicated in Fig. 48.

EXERCISES

1 Make a copy of Fig. 48 in pencil with freehand lettering for titles, etc.

2. Take a sheet of paper and indicate by conventional signs in suitable position the following conditions A macadamized road runs diagonally from the upper left to the lower right-hand corners, with common dirt roads running from about the third points towards the upper right and lower left-hand corners. At the junction of the upper of these roads and the main road there is a small town consisting of four stores, church, school, etc The surrounding country is given over to farms with houses, outbuildings, orchards, cultivated fields with various kinds of fences, etc Draw five such farms dividing the land in a suitable manner and introducing all the signs of Fig. 48 Suppose a large stream to cross the map about the center with bridge at road and branches from north and south As an example of a map drawn with these signs see the Hunterstown map in the back cover. Note that this map has been reduced from a larger drawing and the size of the individual signs in this problem should be taken from Fig 48

Art 21. Enlargement and Reduction

It is sometimes desirable to change the scale of a map, either enlarge or reduce it. This can be done by means of a special drafting instrument, the pantograph, or by the **method of squares.** The latter method is quite rapid and easy and involves both drawing conventional signs, as well as a problem in scales.

Suppose, for example, we desired to enlarge one square mile of Fig. 13, a U. S. G. S. map drawn with an R. F. of 1 . 62,500, so as to represent the square mile in question to a scale of 1 . 10,000. This might be done in order that we could use the data shown on the U S. G S map as a basis for a complete military sketch. That is, we could enlarge this section, then go out in the field and sketch in a large number of details not shown on the U. S. G S. map.

The procedure would be as follows:

1. Compute the length in inches which represents one mile on a map drawn with an R. F. of 1: 62,500. (See Art. 9.)

2. Draw a square with the above dimensions representing

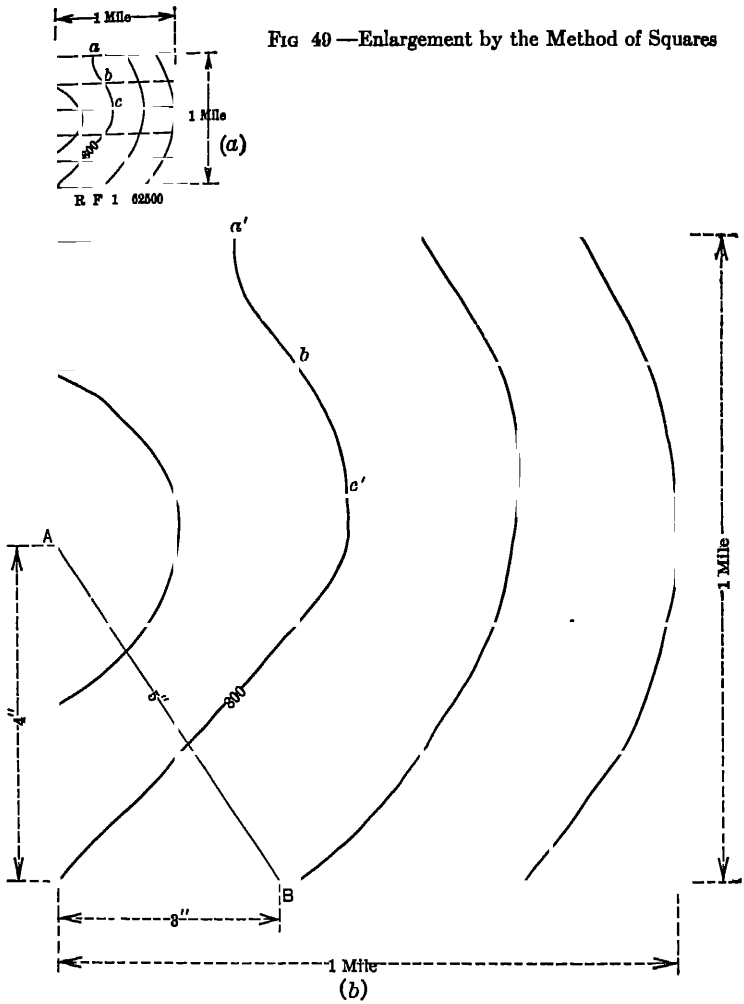


Fig 40—Enlargement by the Method of Squares

one square mile and covering the required section of the U. S. G. S. map.

3. Divide this square into say twenty-five smaller squares by dividing each side into five equal parts. This may be done

by trial, with a scale (see Fig. 24) or by the method used in constructing a graphical scale. (Fig. 23.)

4. Compute the length in inches which represents one mile on a map drawn with an R. F. of 1: 10,000.

5. Draw a square of this size on a sheet of drawing paper and check the angles to be sure it is a perfect square. Fig. 49. Note that the construction of such a square is quite easy if a drafting triangle is available. If no instruments are available fold over a piece of paper for a straight edge and lay out two sides of the square making a right-angled corner by eye. Check this in the following manner: Along one side lay off four inches and along the other three inches by means of the engineer's scale, Fig. 24, obtaining two points A and B, Fig. 49*b*. Scale the distance between A and B. If this distance is five inches the angle has been properly drawn. If it is not the lines should be corrected and again tested. Any fraction or multiple of 3, 4 and 5 can be used.

6. Divide the square so constructed into twenty-five smaller squares as was done in (3).

7. Transfer the details from the small map to the enlargement by eye, square by square. For example, we note in Fig. 49*a* that the 800 contour crosses the center of the top of the second square at *a*. This point is therefore marked at the center of the top of the corresponding square of the enlargement at *a′*. The next point noted on this contour is where it crosses the corner at *b* which corresponds to *b* in the enlargement, etc. Between these guiding points the line is drawn by eye

It will be noted that the small map could be enlarged to the larger scale by drawing simply the outlines of one mile squares and sketching in the details from the map to the enlargement by eye. This would give a rough enlargement, but by dividing both the map and the enlargement into smaller squares the errors due to enlargement by the eye alone are reduced and such errors as do occur are practically limited to minor discrepancies in the smaller squares.

EXERCISE

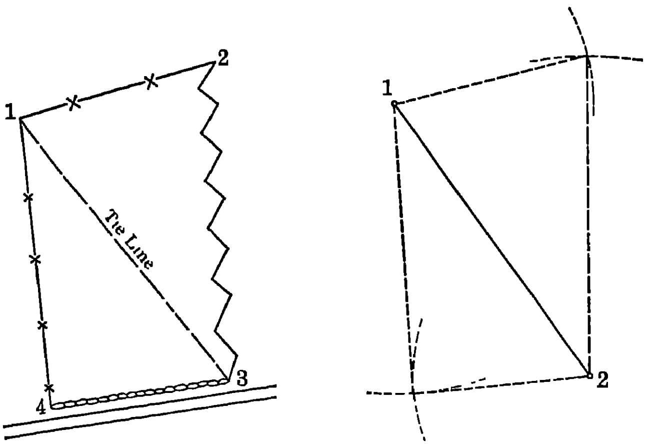
1 Select any square mile of Fig 13 and enlarge this portion of the figure to a scale of 1 10,000 as described above. Give all computations on the reverse side of the drawing

CHAPTER II

FLAT MAPPING

ART. 22. SURVEYING AND MAPPING

SURVEYING, of which mapping is a part, consists in making such measurements between various points on the ground as are necessary to plot the relative position of these points in the form of a map. Thus in making a map we want to show the location of houses, roads, etc., and this is done by deter-



(a) Measurements (b) Plotting

FIG 50 —Mapping by Distance

mining the relative positions of points which define these objects, such as the corners of a house, points at bends in the roads, etc.

In order to determine the relative position of points on the earth's surface measurements of distances, or angles and distances, are necessary. Fig. 50a, for example, shows a piece of land bounded by four straight fences. In order to make a map of the boundaries of this property we must

determine the relative position of four points—the corners. That is, we must make in the field a sufficient number of measurements to enable us to plot these four points in their proper location on a map. The boundaries are simply straight connecting lines. Now if we measure the distance between each of these points, 1 to 2, 2 to 3, 3 to 4, and 4 to 1 it will not be sufficient to locate them, as there are an infinite number of four-sided figures which can be drawn with these four distances as sides If, however, we measure either diagonal, say 1 to 3, the figure is fixed, as this "tie line" divides it into triangles and when the three sides of a triangle are known the

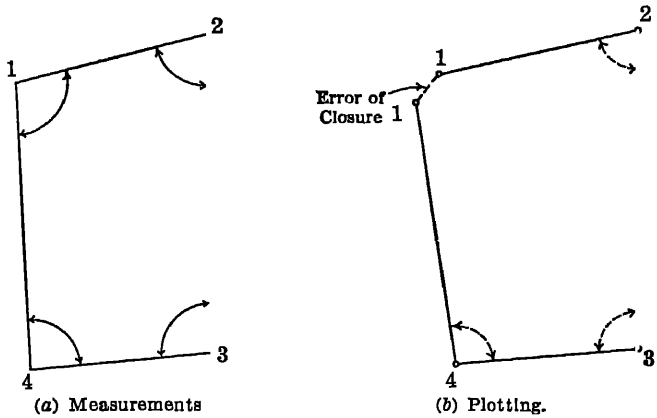
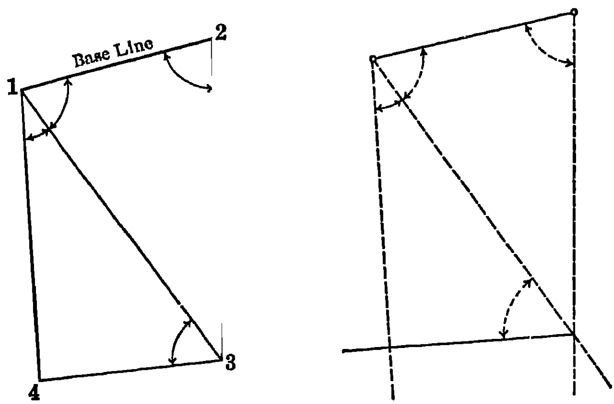


FIG 51 —Traversing Method

corners are fixed. The map is plotted by laying off the length 1 to 3 on our drawing to any scale which we wish to use for our map. Then, with 1 as a center we can draw a portion of a circle having a radius equal to the distance 1 to 4 to scale and with 3 as a center an arc of radius 3 to 4 to scale. Where these arcs intersect, as shown in Fig. 50*b*, is the location of the point 4 on our map. The same scheme of division into triangles may be used for areas of a greater number of sides.

Fig. 51 shows another method of making a map of the same area. In this case the four angles are measured as well as the four sides thus fixing the figure. Angle measurements can be plotted by means of a protractor or Fig. 22*c* may be used for this purpose. That is, the measured length of 1 to 2

may be laid off to scale. Then at the point 2 we may lay off the angle 1–2–3 by marking it on a piece of tracing paper held over Fig. 22c, and transferring our lines to the map. We then lay off the distance 2 to 3 in the direction so determined, etc. Note that in doing this, as shown in Fig. 51b, it frequently happens that when we plot the point 1 from the point 4 it will not come exactly at the point we originally selected for 1 in starting our map. This may be due to small errors made in plotting or in the measurements themselves. Indeed we made two more measurements than were necessary to fix the figure—we could also have plotted the four points if we had not known the last distance or angle or, in fact,



(a) Measurements (b) Plotting

FIG 52—Mapping by Triangulation

with any one distance or angle missing. On the other hand, if we measure all the distances and angles, and plot them in the manner above described, and find that the plotting of the point 1 from 4 agrees very closely with our starting point it shows that our measurements and plotting were both well done and free from large errors, that is, the "error of closure," or distance between these two plottings, is a reasonable amount. In practice it will never be zero unless the errors accidentally balance.

The above method of mapping by measuring all distances and angles is known as **traversing**. Another method, which is more rapid and better for certain kinds of work, is **tri-**

angulation. In this method we measure all the angles but only one distance, which is known as the "base line." Thus in making a survey of the field already discussed we would measure any one side, say 1 to 2, and the angles 3–1–2 and 1–2–3; also the angles 4–1–3 and 1–3–4, Fig. *52a.* The length 1 to 2 can then be plotted to scale, then the angle 3–1–2 can be laid off at the point 1, giving the direction of the line 1–3, and the angle 1–2–3 at the point 2, also giving the direction of the point 3. The intersection of these two lines, as shown in Fig. *52b,* determines the location of the point 3. The point 4 is determined in a similar manner by plotting directions from 1 and 3 with the line 1–3 as a base.

EXERCISES

1. Given the following distances in feet between six points plot their location to the scale 1 inch equals 100 feet 1–2, 260; 2–3, 273, 3–4, 94; 4–5, 277, 5–6, 171 6–1, 298; 1–5, 317, 2–5, 356, and 3–5, 281
2. Given the following interior angle and distance measurements plot the traverse to the same scale as in (1) Distances in feet 1–2, 169, 2–3, 122, 3–4, 76, 4–5, 221, 5–6, 174, and 6–1, 204. Angles 1–2–3, 41° 30′; 2–3–4, 277° 0′; 3–4–5, 108° 10′, 4–5–6, 60° 50′, and 5–6–1, 126° 0′.
3 In Fig 52 the base line measures 500 yards. The measured angles are as follows 3–1–2, 68° 15′, 1–2–3, 76° 30′, 4–1–3, 32° 40′, and 1–3–4, 59° 10′. Plot the points to a scale of 12 inches equals one mile.

ART. 23. PACING AND THE SCALE OF PACES

It will be clear from the preceding article that one of the fundamental operations in mapping or surveying is the **measurement of distance.** It is also clear from our studies of maps that maps show horizontal distances; that is, if we have two points on a hillside, such as *A* and *B*, shown in profile in Fig. 53, the distance between these points as shown on a map would be the horizontal distance *AC*. In making our measurements in the field it is possible to measure the horizontal distance directly by holding a tape on the ground at *B* and lifting the lower end sufficiently high above *A* so that the tape will be horizontal. It is also possible to measure the inclined distance along the line connecting *A* and *B*, and then by measuring the vertical angle *BAC* to compute mathematically, or plot up the triangle *BAC* and by scaling, get both the

horizontal distance AC as well as the distance CB, which is known as vertical distance or difference in elevation between A and B. In connection with distances it should be always borne in mind that when we speak of distance we mean horizontal distance.

In sketch mapping the method used for measuring distance is **pacing.** In measuring distance in this way two different plans can be followed: 1, by careful pacing between points, which have been accurately laid out with a tape, the pacer may so adjust his pace that he will learn to pace one yard. This method is largely used by surveyors who make considerable use of pacing in locating the smaller details in topographic

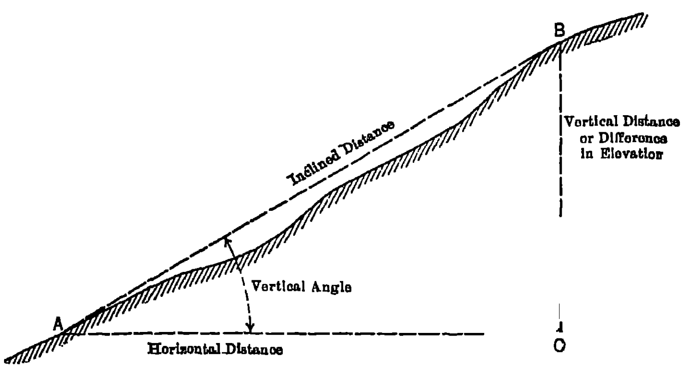


FIG 53 —Profile Showing Distance Measurements

mapping and other work; 2, the pacer can use his natural pace and find out how many inches this is. Any distance can then be measured in paces and the number of paces converted to inches, feet or yards. The latter is the procedure followed in military and sketch mapping, because the first method, while very convenient, as the change from paces to feet or yards is simple, is artificial, and when the pacer becomes tired, as is the case when many or long distances are measured, he drops back to his natural pace The surveyor, who measures only short distances by pacing, therefore uses an artificial step or pace of one yard. The sketch mapper, who frequently measures long distances by pacing, finds it desirable to use his natural step.

To determine the natural pace or step a distance should

be measured out with the tape over level ground for the first practice. Having paced this distance and determined the average number of inches per step, a second series of distances should be laid out with tape over sloping ground. The pacer must now practice on these sloping distances so as to learn to lengthen his step by the proper amount in order that he will take the same number of paces as he would have taken had the ground been level. In other words, he must learn to judge slopes and how to lengthen his step so that he will secure not the sloping distance, but the horizontal distance between points. Inasmuch as the accuracy that can be secured by pacing is about 1 in 80 to 100, that is, a distance of 80 or 100 feet or yards can be measured by pacing with the probability of the error not being over one foot or yard in either direction, it is unnecessary to give much attention in lengthening the

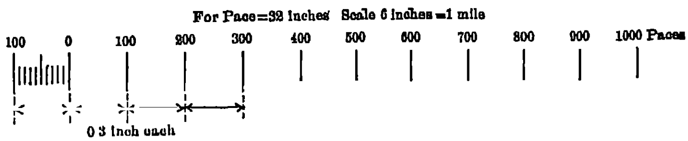


FIG 54 —Scale of Paces

step on slopes of less than about ten or fifteen per cent. This means that any pacing along roads, where such grades are practically never found, no attention need be paid to lengthening the step. Also remember that we naturally lengthen our step when going down a hill and it is only necessary to pay particular attention to lengthening it when going up a slope.

Having determined the length of the step it will be found convenient to make a **scale of paces** in order to simplify the plotting on a map of distances which have been placed. A scale of paces is similar to the reading or graphical scale on a map except that it gives distances on the map in paces instead of in feet, yards or miles Thus if the map is to be drawn on a scale of 6 inches equals 1 mile and the length of pace is found to be 32 inches, we can make a scale which will enable us to plot paces directly on the map and save ourselves the labor of first converting paces into inches and then into feet or yards The procedure in making such a scale is as follows:

Taking one hundred paces as the largest division on the scale, this would equal 3200 inches on the ground, Since the map is to be drawn at the scale of 6 inches equals one mile (R.F. is 1 : 10560), it is clear that one hundred paces, or 3200 inches, would be represented by 3200 : 10560 or 0.30 of an inch on the map. The scale is constructed by ruling off successive lengths of 0 30 of an inch on a strip of heavy paper, marking these 100, 0, 100, 200, etc., as shown in Fig. 54. The first space from 100 to 0 is divided into 100 parts by the same method used for the graphical scale as already described in Art. 11.

EXERCISES

1. Lay off a length of 300 to 1000 feet with a tape over level ground and determine your natural step in inches.
2. Construct a scale of paces with main divisions of 100 paces and an end portion graduated to read to ten paces for use in plotting a map the scale of which is 12 inches equals one mile
3. Select four or five points in the field, the corners of buildings, walks or other objects, and doing the necessary pacing, map them by pacing alone using the scale constructed in (2) above

Art. 24. The Sketch Case and Traversing

In sketch mapping the distances are actually measured by pacing as above described, but the horizontal angles are transferred directly to the map and not measured in the usual units. In other words the plotting is done and the map is made in the field where this procedure is possible and where the sketcher has the land in view as he does the work.

The methods of flat mapping will first be described, followed by the methods of locating contours. For contours elevations are necessary and these are secured by actually measuring the vertical angle, or the angle of one point above or below another. For this purpose either a slope board or clinometer is used as will be described in Art. 28.

The instruments used for military mapping are contained in a small carrying case or **sketch case** * and comprise: 1. a small drawing or sketch board, 2. a light tripod, 3. a sighting scale or "alidade," 4. a slope board, and 5. paper, thumb

* See Appendix 2

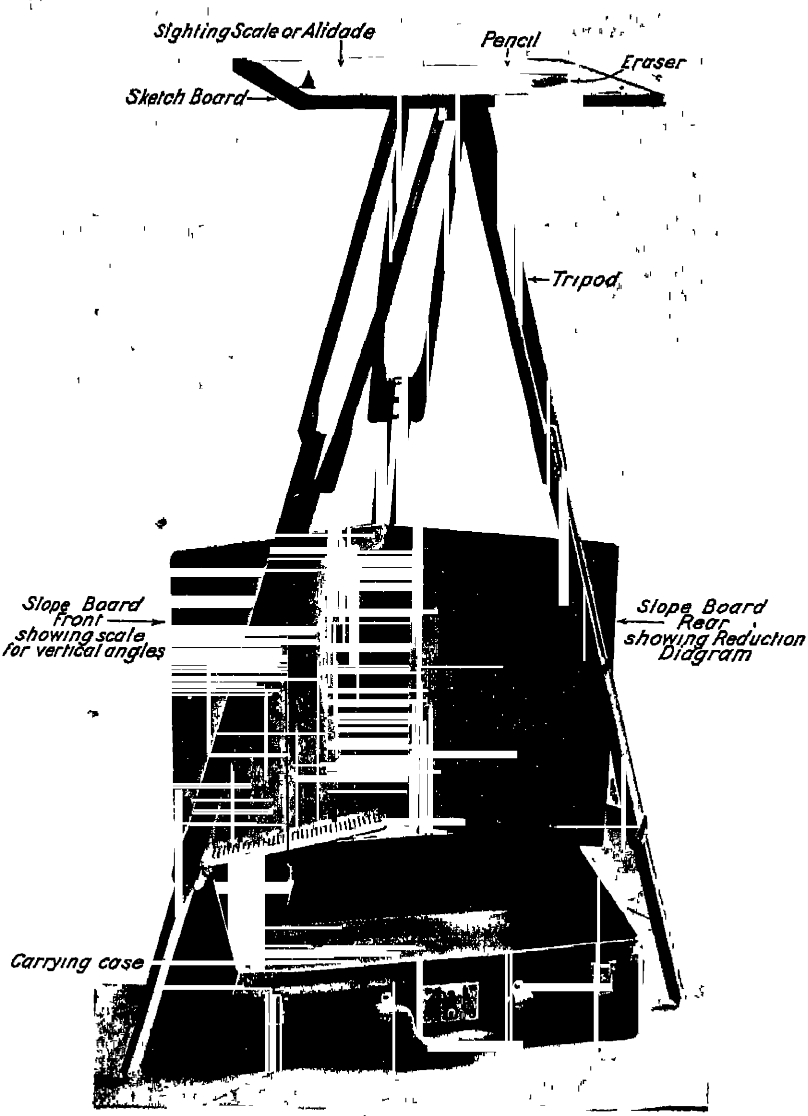


FIG 55 COMPLETE SKETCH CASE OUTFIT

tacks, pencil, eraser and pins. A complete outfit is shown in Fig. 55. The tripod may be fastened to the sketch board by means of a small thumb screw like that on any camera tripod. The board can thus be set up at any point, by moving the legs it can be approximately leveled by eye; with the thumb screw loose it can be turned in any direction, and by tightening this screw is held firmly in any position. The drawing paper is secured to the board by thumb tacks. The triangular sighting scale or alidade is made of wood weighted with lead so as to prevent its movement by wind, etc. Pasted on its edges should be a reading scale for the map that is to be made, and scales of paces also corresponding to the scale of the map and to the pace-scales of the members of the party. In fact it is desirable that each man have an alidade with his own pace scale on it. This alidade serves three purposes: 1, it is used in transferring to the map the direction of various points from the point where the board is set up. 2, the scales of paces on its faces are used in plotting distances on the map, and 3, the reading scale is used in scaling distances from the map.

The two principal types of topographic surveys are road surveys and area surveys. The former, known as **road mapping** in military work, has as its object the mapping of a narrow strip of country on either side of a road or other line, while in the latter, known as **position sketching,** a topographic map covering a certain area is required Engineers make surveys of a similar nature, using more accurate instruments—the first for use in locating roads, railroads, canals, etc., and the latter in connection with plans for reservoirs, etc., which cover an area rather than a narrow line.

The best method in using the sketch case is to do road work by traversing, and area work mainly by triangulation.

The use of the **traversing** method for mapping a road is illustrated by Fig. 56, which represents a portion of a road with principal bends at *B*, *C* and *D* We would set up our sketch board at *A*, Fig. 56*a* and turn and clamp the board so that its edges were about north and south as shown in the figure and so that the length of the board is in the general direction of the road. We now select a point on the board,

a, to represent the point *A* on the ground. Place a pin at the point *a* on the board and putting the triangular weighted sighting scale or alidade next to the pin turn the alidade so that it points at the next point *B*. A pencil line may now be drawn along the edge of the alidade, giving the direction of *B*. The distance to *B* is then paced and the point *b*, representing *B* on the map is found by plotting the paced distance

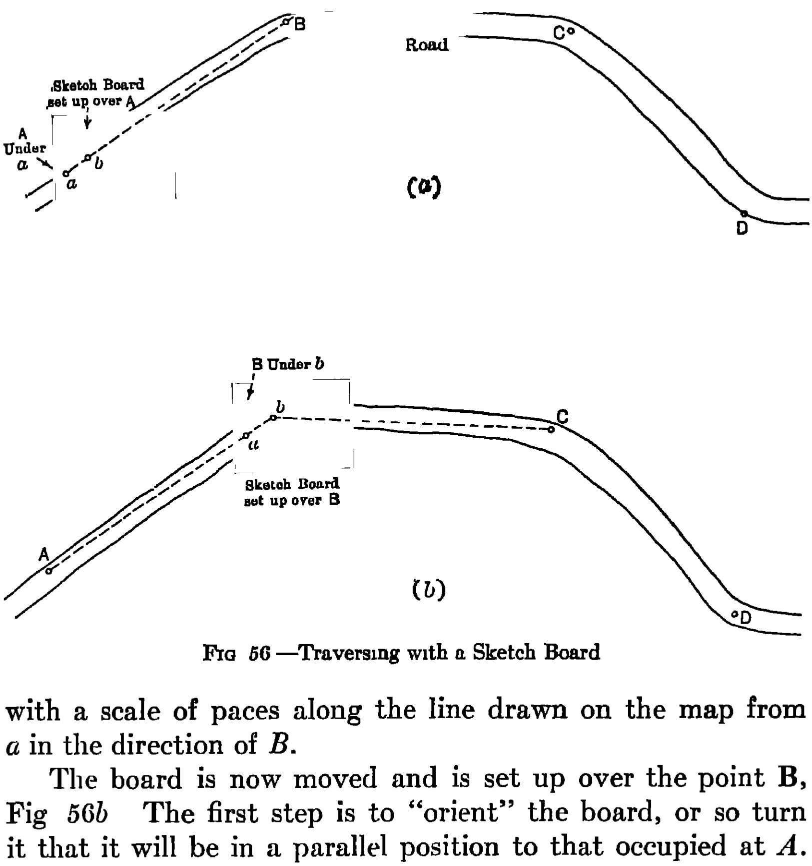


FIG 56 —Traversing with a Sketch Board

with a scale of paces along the line drawn on the map from *a* in the direction of *B*.

The board is now moved and is set up over the point **B**, Fig 56*b* The first step is to "orient" the board, or so turn it that it will be in a parallel position to that occupied at *A*. This is done by placing the edge of the sighting scale on the line *ab*, loosening the screw which secures the board to the tripod and turning the board so that the alidade, and hence the line *ab*, point back at *A*. The board is then clamped, the pin moved to the point *b* on the board, the alidade pivoted about *b* until it points at *C* and the direction of *C* from *B* is

drawn. In this way the angle ABC is transferred directly to the map. We now locate c by pacing and plotting the distance bc, move the board to C and repeat the operation.

Note that the mapper must select the set-up points A, B, etc. These points should generally be taken as far apart as possible and at the principal bends in the road which can be sketched in freehand between them. Short sights are to be avoided in traversing with the sketch board, as they introduce errors in sighting. Also remember that it is necessary from each set up to see the previous point as well as a suitable point in advance.

It will be found desirable to have at least two short poles

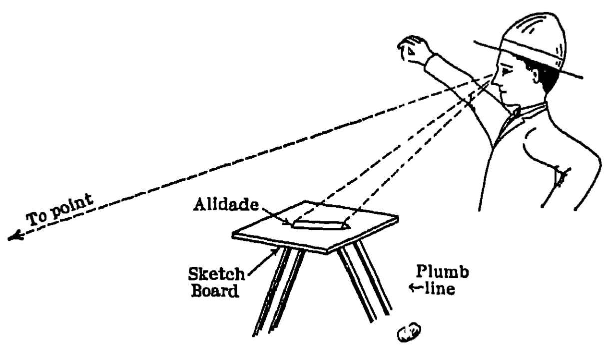


FIG 57 —Method of Sighting for Points Much above or below Level of Board

which can be stuck in the ground at the last and next set up, to use in temporarily marking them as well as in sighting. Also in sighting do not stand close up to the alidade, but a few feet in back of it, as a better sight can be made this way. On steep grades, where one point is much higher or lower than the other, the beginner may have difficulty in sighting along the alidade. A pin may be put in each end of the top edge to assist in doing this, or a piece of string with a stone on the end may be held in the hand and used as shown in Fig. 57. The hand is moved until the string is on line with the eye, the board and the next point so that a glance down the string, without moving arm or head, will show whether the alidade is also on this line.

The traverse shown in Fig. 56 begins at one point, A, and

ends at another point, *B*. It is an **open traverse**, inasmuch as it does not continue around and return to the starting point, thus forming a completed polygon or **closed traverse.** There is no check on the accuracy of an open traverse, but in the case of a closed traverse the error of closure, mentioned in Art. 22, gives a clear indication of the total error of the work. Thus in running a closed traverse we finally sight, pace, and can plot the location of the first point from the last. This

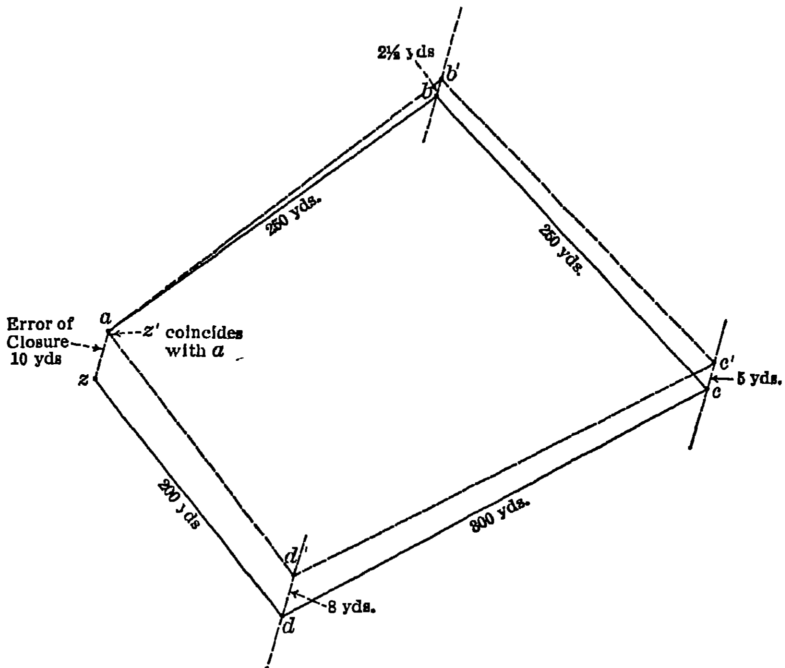


FIG 58 —Distribution of Error of Closure.

location will not agree by a number of yards, probably by about one yard for every 100 yards' length in the traverse The student should understand that an error of closure is always to be expected and that while a small error of closure indicates careful and accurate mapping it may not indicate efficient work. This is true because careful and accurate work requires time, and time is either valuable or costly. Hence the man who does work of a higher degree of accuracy than

is required for the purposes for which his work is to be used, is not economical in his labor and is not an efficient mapper

Recognizing, therefore, that an **error of closure** will always be present the next step is to distribute this error in a reasonable manner so that the map will "close" and its probable accuracy be increased. This can be done by drawing lines through each set-up in the map of the traverse parallel to the error of closure as shown in Fig. 58. Each plotted set-up point is then moved along this line by an amount proportional to its distance along the traverse from the starting point. In Fig. 58 the point a is left as it was; b is moved to b', as shown by the dotted line, by an amount bb', which is one-quarter of error of closure a because the distance along the traverse from a to b is one-quarter of the total length of the traverse. Similarly, c is moved $(500-1000)$ of 10 or 5 yards, etc. These adjustments can usually be made by eye. The final adjusted traverse is a, b', c', d', a.

In making a more complete map the details, such as houses, fences, etc., would be located from the various set-ups and drawn on the map. The various methods of doing this are described in the next article.

EXERCISE

1. Run a closed traverse with the sketch case as described above and adjust the same. Remember in selecting set-ups that it is necessary to see the last point as well as a suitable point in advance Do not set up in the middle of a road or street as it will probably be necessary to move the board to allow traffic to pass and this means that the board will have to be oriented again. Not over three men should work together and the positions of plotter, pacer and rod man should be changed at frequent intervals Accuracy and rapidity require an orderly and systematic scheme of work with each man thoroughly familiar with the procedure and trained to his part Use a scale of 12 inches equals one mile. Show a pointer on the map drawn by compass or watch as described in Art. 9 Also letter a title, names of party and other suitable marginal information Set-up points should be marked by small circles.

Art. 25. Location of Details

The road map produced by traversing, as described in the last article, is of course devoid of all details and shows only the line of the road. This would also be true of a map produced by triangulation alone, which would show only the location of the set-up points in the area. Indeed the scheme of sketch mapping consists in locating on the map, by either traversing or triangulation, the point of set-up of the sketch board and then drawing in the surrounding details which go to make up the completed map from these points.

In mapping by the traversing method three schemes are used to locate the details, namely: radiation, intersection and offsetting. Any detail, reasonably near the point of set-up, the distance to which may be easily paced, that is, the ground is fairly level and obstructions absent, is best located by **radiation.** This method, Fig *59a,* consists simply in drawing a "ray" from the set-up point in the direction of the object, the distance to which is paced and plotted in the usual manner. This is the same procedure exactly as is used in locating the next point in advance in traversing.

It frequently happens that we desire to show on our map objects some distance from the point of set-up, hence requiring considerable time for pacing, and which may not be easily accessible from the set-up point. Such objects are located by drawing two rays towards the object from two different set-ups. For example, the building in Fig. *59b* could be located by radiation if we paced the distance from the set-up point *A* to the object, but it will probably save time to locate this building by **intersections** simply drawing a ray toward it from the point *A* and when we occupy the station *B,* draw another ray toward the object, the intersection of these two rays giving its location on the map.

It will be evident that objects near the traverse line, but not near points of set-up, cannot be accurately or quickly located by either of the above methods. Intersections would give a poor location, ast he two rays would intersect at a very flat angle. For such details the method of **offsets** is best applied. Thus, in Fig. *59c,* the building shown is best

located by measuring the number of paces from A along the traverse line AB to a point directly opposite the object c and then pacing the distance at right angles to the traverse line, CD (known as the offset), to the object itself. In many

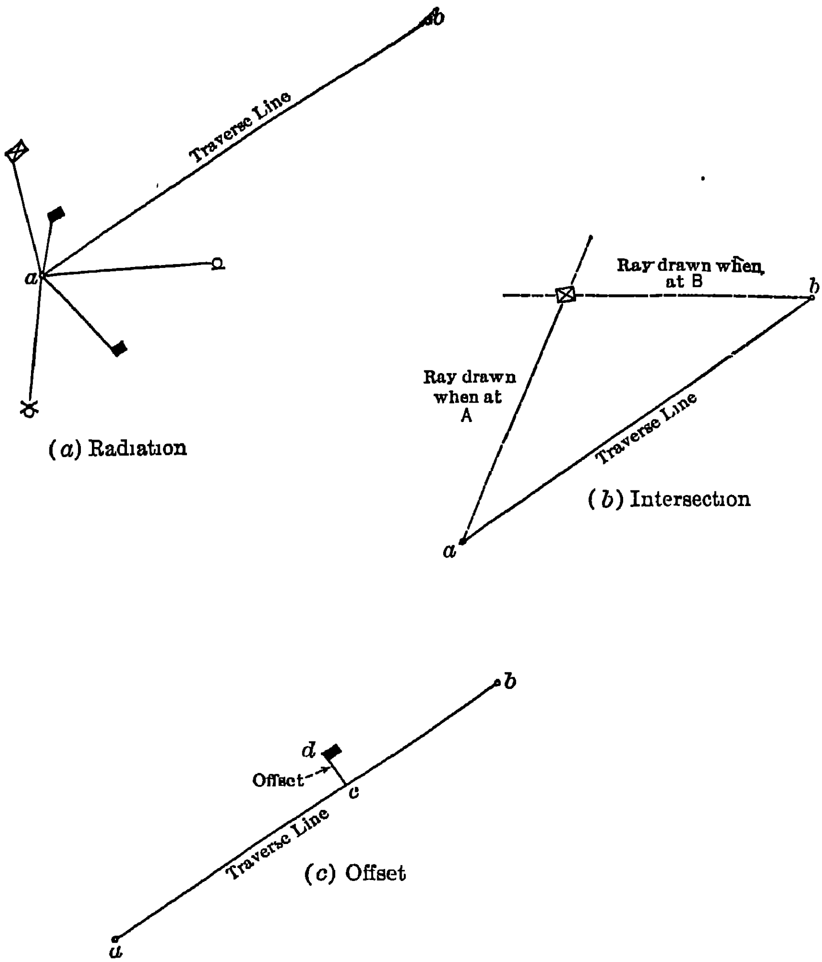


FIG 59 —Methods of Locating Details

cases it is unnecessary to actually measure the offset, as an experienced mapper can estimate it with sufficient accuracy.

Students should understand that in the process of road mapping both the traversing and the location of details are

carried on simultaneously and the details are mapped in from each set-up as the traverse is run. In order that the mapping may proceed rapidly and in a systematic way which will eliminate blunders the following procedure should be followed:

1. Set up the board at the initial point selected for the first set-up, turn the board so that its edges are north and south, and by means of a compass or watch draw a north pointer for the map.

2. Select a point on the board to represent the initial or starting point which the board is set up over. In selecting this point estimate where it had best be placed so that the map will not run off the edges of the paper.

3. While the mapper is doing this, one of his assistants should advance and select the next station, marking it with a pole. Remember the requirements in connection with this selection and, in addition to those already mentioned, bear in mind that it should be chosen with reference to a view of the surrounding details, so that proper sights can be obtained to them to locate their positions on the map.

4. The instrument man may now draw a ray to this next station while his assistant paces the distance.

5 The mapper should now look over the section of country between him and the next set-up and decide which one of the three methods he is going to use in locating on the map the various required details.

6. All objects which are to be mapped by radiation should now be plotted.

7. Rays are drawn towards objects which will be located by intersection and a note is made on each ray describing the object sighted.

8. After this work has been done it is best to place the alidade along the ray to the advance station and note if the board has accidentally moved during the work.

9. Remove the board from tripod and hold it on the left arm. Sketch in all objects located by offsets as you walk up to the next station. One of the other members of the party should do the pacing, thus allowing the instrument man to give his full attention to the sketching.

10. Set up at the second point. Orient back on a pole left at the previous set-up and proceed to select a point in advance, etc., in the same manner as described above.

EXERCISE

1 The traverse run as in the preceding exercise should now be run as a complete flat road map, locating all details from each set-up as above described.

Remember that it will be impossible, even with a large scale such as twelve inches equals one mile, to show all details, and that many details are of little or no importance Do not fail to follow a systematic scheme such as is outlined above and make frequent changes in the assignment of the different members of the party to the various parts of the work so that each man will have practice in mapping, pacing, etc.

Art. 26. Position Sketching

If a closed traverse is run along a road surrounding a certain area of land, it will seldom be possible to locate all of the interior details of the area from the traverse sides. If a map is desired covering the entire area enclosed by the traverse, these interior details may be secured by running either spur traverses from points on the exterior traverse line to interior points, from which the interior details may be seen and located, or preferably by running several traverses entirely across the area and tying these into points on the exterior traverse, thus checking the work.

Besides these methods we may also employ a combination of traversing and graphical triangulation. When the object of the survey is to secure a mapped area rather than a narrow strip of country along a road, the method usually followed is triangulation, and such work is known in military mapping as **position sketching.** Remembering that the general plan of procedure is to locate on the map the point where the board is set up and from this point draw in the surrounding details before leaving for another point where the same process is repeated, it will be clear that the main problem is to locate on the map the point of the set-up and properly orient the board so that these side shots, etc., to the details may be taken

The steps in developing and using a scheme of graphical

triangulation for position sketching are illustrated in Fig. 60 and given as follows: 1, select at some point in the area, preferably near its center, where a long strip of fairly level ground is available, a position for the **base line.** This base line, *AB*, should be of good length compared with the area to be surveyed. At least three, and preferably more, prominent objects (*C*, *D*, *E*) in this area should be visible from both ends of the line, and these should be well located for triangula-

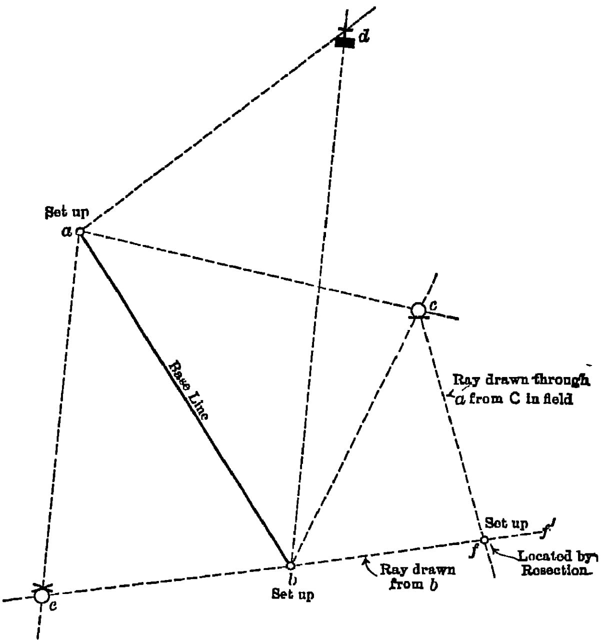


FIG 60—Development of Triangulation Method

tion, that is, they should form good angles for intersections from each end of the base; 2, the base line is next carefully paced and drawn on the sketch board to scale, *ab*, and in such a way that the area to be mapped will not run off the edges of the board, 3, the sketch board is set up at one end of the base, *A*, and is oriented by placing the alidade along the base line and sighting at *B*, the other end of the line A pointer is drawn by means of a compass or watch giving the direction of north; 4, a pin is placed on the map on point

a and rays are drawn with the alidade to the prominent objects *C*, *D*, *E*, etc. The topographer now proceeds to locate such details near the point of set-up as are suitable for location by radiation, and also may draw other lines for **intersections**; 5, the sketch board is now moved to the other end of the base line at *B* and oriented by sighting back on *A*. Rays are carefully drawn through *b* to the objects, *C*, *D*, *E*, etc., which are hence located at *c*, *d* and *e* by intersection. Fig. 60. The topography near *B* is secured by radiation, etc., in the same manner as that near *A*.

Having completed the mapping near the two points *A* and *B*, the mapper will have to move on to other points in the area from each of which he will locate the surrounding details and thus complete the mapping of the area. While it is of course possible to traverse from either end of the base line to a new point of set-up it will very often be found that the distance to a desirable point of set-up cannot be easily paced and hence the mapper resorts to either the resection or what is known as the three-point method, which require no pacing.

In using the **resection** method the next point of set-up *F* is selected and a ray drawn to it before the sketch board is moved from *B*. The board is now taken to this new point *E* where it is set up and is oriented by placing the alidade along the ray *f'b* previously drawn, and sighting back to the point from which the instrument has just been moved. The board is now properly oriented, but we do not know the location of our point of set-up on the ray *f' b*. This may be found by placing the pin on the plotted position of some previously located object such as *C*, *D* or *E*, visible from the point of set-up. The alidade is now pivoted about the point *c* for example, and sighted at the corresponding object, in the field, *C*, which *c* represents on the map. A ray drawn backward from this point intersecting the previous ray will locate the point of set-up *f* on the first ray, *f' b*. Fig 60. The point of set-up is now known and the board oriented, and the mapper may proceed to locate details.

The **three-point method,** mentioned above, gives even more freedom to the topographer than the resection method, as it is not necessary to select the next set-up before leaving

a station. The mapper can pick up his board and move over the area until he finds a desirable position for the instrument. The board can be set up in this new position, oriented and the point of set-up plotted provided at least three objects already plotted on the map are visible in the field.

Several methods are used for solving the three-point problem. One of the simplest of these is known as the trac-

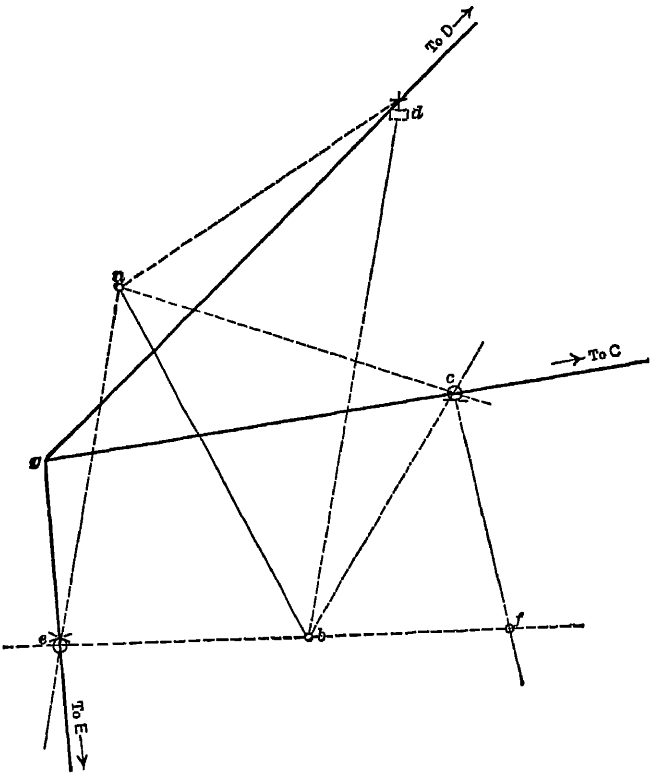


FIG 61 —The Three Point Method.

ing paper method, Fig. 61. A piece of tracing paper is placed on the board and held down with tacks. A point G is selected in the center of the paper and rays are drawn from this point in the direction of the three above-mentioned objects in the field, C, D, and E. The paper is now untacked and is moved around over the map until these three rays pass through the three corresponding objects c, d, and e, as plotted on the

map. It will be found that only one position of the tracing paper will satisfy this condition and the center point of the rays for this position of the paper gives the location of the point of set-up on the map. In Fig. 61 the map of Fig. 60 is shown faintly by dotted lines while the three rays drawn on the tracing paper from the point of *g* are shown by solid lines. The position of the tracing paper illustrated shows the three rays passing through the three points as required, thus locating the point *g*. Before proceeding to the location of details it is necessary, however, to orient the board. This can be done by placing the alidade on any one of the three rays such as *gc*, and turning the board so that the alidade sights on the corresponding object *C* in the field.

It will be obvious from the above description that the first thing to do in mapping an area by triangulation is to plan out a general scheme of procedure which will effectively cover the area to be mapped. It is also desirable to use as many checks as possible, such as intersections and resections, to make certain of the location as the work proceeds.

EXERCISES

1. Complete the mapping of the interior portion of the area used in the exercise of the previous article Do this by running cross and spur traverses introducing, if possible, at least one set-up by the three-point method.
2. Make a position sketch of an area by the triangulation method including selection and measurement of base line, intersection, resection and the three-point method as described above.

CHAPTER III

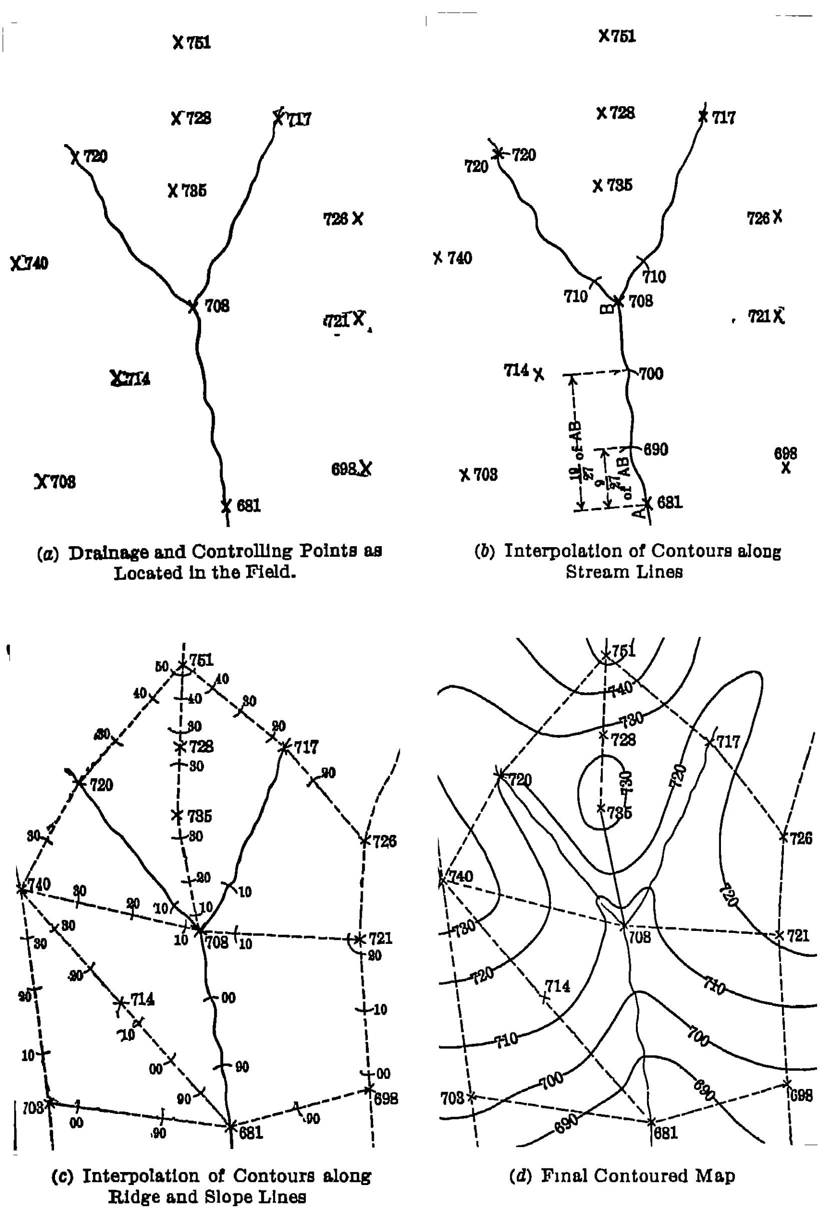
CONTOUR MAPPING

ART. 27. CONTOUR INTERPOLATION

THE methods of mapping previously described result in a flat map, showing the main topographic features of the country but devoid of relief. The problem of locating and showing on the map, by means of contours, the various hill and valley forms is more difficult and requires more skill and ability on the part of the mapper than the production of a simple flat map.

The first step in contouring is to obtain a sketch of the **drainage** or stream lines. This is simply part of the flat mapping work and requires the location on the map of points at the principal bends in the streams so that they may be properly sketched in between. The relation of drainage to relief has been pointed out in Art. 5 and the necessity of obtaining a careful sketch of the drainage before proceeding to the contouring is quite clear.

Having obtained the drainage lines the next step is to secure the location and elevation of certain **controlling points** which will enable us to interpolate and sketch in the contours. The selection of these controlling points and the method of securing their elevation is discussed in Art. 28. Their location on the map is secured by the flat mapping methods already described. The result of this work is shown in Fig 62*a*, which illustrates the drainage lines of a certain area and shows also the location and elevation of a number of these controlling points. This is sufficient to permit us to draw on our map suitable contours to represent the relief. In actual practice this work is always done in the field when the ground is in front of the topographer and the small variations in the form of the surface features can be noted and properly rep-



(*a*) Drainage and Controlling Points as Located in the Field.

(*b*) Interpolation of Contours along Stream Lines

(*c*) Interpolation of Contours along Ridge and Slope Lines

(*d*) Final Contoured Map

FIG. 62 —Steps in Contour Interpolation.

resented in sketching in or interpolating the contours from the drainage lines and elevations.

As a preliminary practice in the work of drawing contours Figs. 62*a*, 63, and 64, which show the results of field measurements, can be used. The process of **interpolation** is as follows:

1. Study the map and obtain a general idea of the main ridge lines in their relation to the valleys and to the given elevations. This will give us a general idea of how the contours will run and their general form. In connection with this study review Art. 5 in which the relation of drainage and relief is discussed. Bear in mind that contours will bend up the streams and down the ridges and that ridge lines must separate all streams.

2. Locate the points where the contours will cross the streams in the following manner: Select any two adjacent points on a stream and assume the stream to have a uniform slope between these points, for example, the points 681 and 708 in Fig 62*a*. If we are placing 10′ contours on this map there will be a 690 and 700 contour crossing the stream between these points. If the slope is uniform the stream must rise at a uniform rate, a total rise of 708 minus 681, or 27 feet between these two points. It is therefore true that a point on the stream having an elevation of 690 feet or 9 feet above the lower point will be located $\frac{9}{27}$ or $\frac{1}{3}$ of the distance from the 681 point toward the 708. We may, therefore, estimate by eye in Fig. 62*b*, $\frac{1}{3}$ of the distance from the lower towards the higher point and mark this for the 690 contour. The 700 contour being $\frac{19}{27}$ of the distance or a little over $\frac{2}{3}$ from the lower point toward the upper can be estimated in the same way, and may be drawn with sufficient accuracy at the $\frac{2}{3}$ point or slightly above it. In connection with contours remember that the elevation of a contour must always be divisible by the contour interval. This method of interpolation should be followed out for all the streams and will result in locating the points where the contours cross the streams, as is illustrated in Fig. 62*b*

3. No ridge lines are shown on this map, but by studying the drainage and noting the elevations we may draw such lines to be used only as construction lines in filling in the con-

tours. Thus, it is obvious that there must be a ridge dividing the two forks of the stream which branch out at the 708 point. This ridge will run as shown by the dotted line in Fig. 62c from the 708 point to the high point 735 and continue on through a saddle at 728 to the higher point 751 just beyond which it passes off the map. It is also clear that there must be higher ground on both sides of the stream and it will be assumed that the 726, 721 and 698 points on the right-hand side mark the crest of this ridge, while the same is true of the 740 and 703 points on the left-hand side of the sheet. These points are therefore connected by dotted lines as indicated and contour points are interpolated along these lines in exactly the same manner as along the stream lines, Fig. 62c.

4. Additional construction lines, running directly down the slopes, that is, approximately at right angles to the contour and drainage lines, are also drawn and contour points are located as before. The result of this work is shown in Fig. 62c. Note in connection with these latter lines, such as that joining the 721 point with the 708 point that they must be drawn directly down the slope, inasmuch as we assume the ground to have a uniform slope between them. It is obviously not permissible to interpolate between points like the 721 and 735, as such a line would cross the drainage and we know that two slopes would be involved, first a downward slope from 721 to the stream and then an upward slope from the stream to 735. Furthermore we could not join the 708 with the 703, as this line would not run directly down the slope and as the 714 point in between indicates that a spur of the ridge runs out at this point requiring a decided bend in the contours. It is permissible to interpolate between two points only when the slope of the ground between them is uniform, i e., when the profile of a line joining them would be a straight line. It will be clear from this discussion that the topographer must use care in selecting these controlling or critical points in the field and must so choose them as to properly define the ridges and abrupt changes in slope.

5. Contours may now be lightly sketched in by joining the interpolated points having the same elevation on the various stream, ridge and slope lines. The spacing should

then be adjusted and the final contours drawn in and numbered as shown in Fig. 62*d*. It is in connection with the sketching in of the contours between these interpolated points that considerable thought and care must be exercised. This should always be done in the field where the sketcher can see the form of the hill or valley which he is mapping. This makes it possible to draw in and allow for many irregularities or peculiarities of form which cannot be attempted at all in an office exercise such as that given.

EXERCISE

Following out the method above outlined, (1) place 10′ contours on the field sketch shown in Fig. 63, (2) place 5′ contours on the sketch shown in Fig 64 Note in particular in connection with this figure the swamp area which indicates a flat level section and the saddle in the hill in the lower right-hand corner at the 821 point It is also true that the data given on these sheets is, in some places, insufficient to enable accurate contours to be drawn near the edges of the sheet. The probable form should be shown in such cases

ART. 28. DETERMINATION OF ELEVATION

Two steps are evidently necessary in order to secure the data essential in interpolating contours as described in the preceding article. One of these is the selection and plotting of the controlling or critical points and the other is the determination of the elevation of these points.

The **general plan** for determining elevations is always to start from a point of known or assumed elevation, that is, a point the height of which above some datum, either sea level or assumed, is known. The difference in elevation between this point *A*, and another point *B*, is measured. It may be determined in several ways. Knowing this difference in elevation it is either added to or subtracted from the elevation of *A*, depending upon whether *B* is above or below *A*, thus determining the elevation of *B*. *B* is now used as a starting point and the elevation of another point, *C*, is determined from *B* in the same manner, thus obtaining the elevation of successive points one from another. Obviously this vertical traverse may be continued around and closed back on the starting point, *A*, thus allowing us to check the error in the

work. On the other hand a vertical traverse may be run as an open traverse without any such check, although it is always desirable to use as many checks as possible, averaging up the results obtained for each point and distributing the error in proportion to the distance traversed.

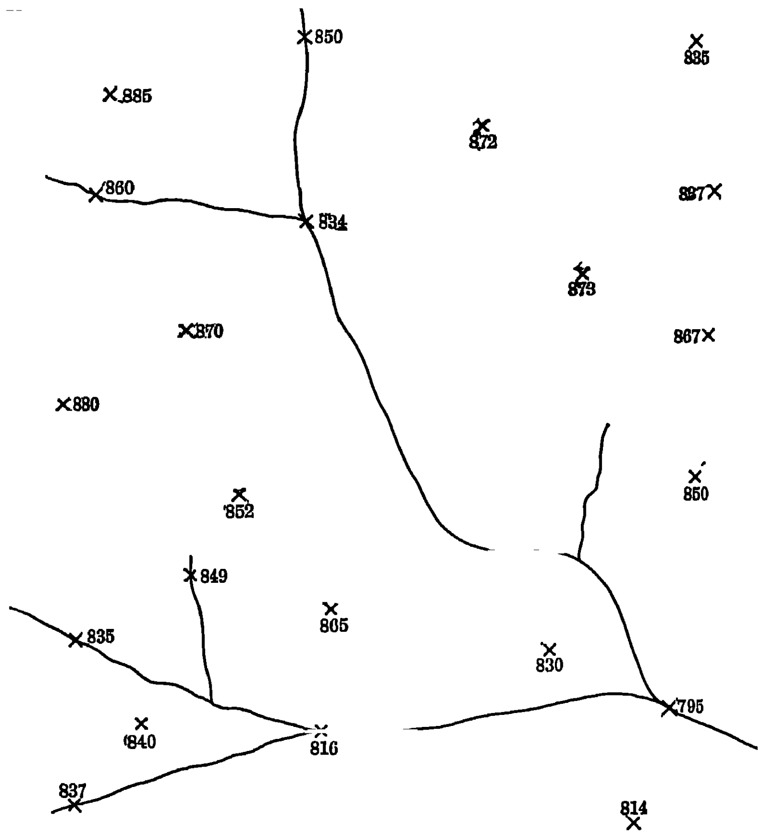


FIG 63 —Contour Interpolations Exercise

The **difference in elevation** between two points can be determined most accurately by means of a **level** instrument. Such an instrument consists of a level bubble, by means of which we can obtain a horizontal line of sight. Thus, in Fig. 65 the difference in elevation between *A* and *B* is obtained by setting the instrument at some point between *A* and *B*

and taking readings on rods held at these two points. The difference in elevation is equal to the difference between these two rod readings, *AC* and *DB*. It frequently happens that more than one set-up of the instrument is necessary and an intermediate point has to be used in order to reach *B*. Work

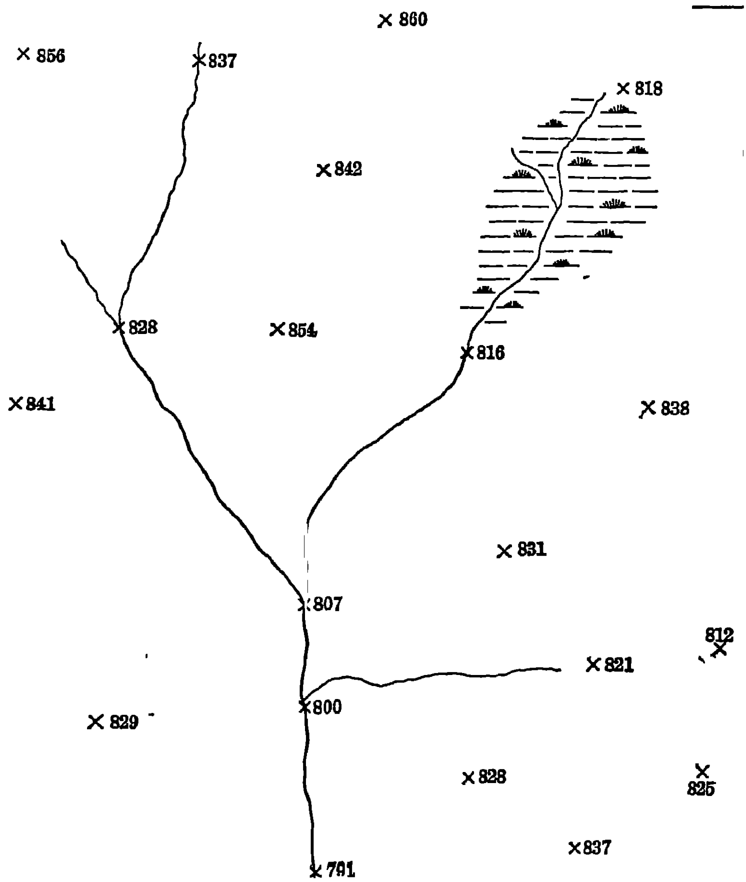


FIG 64—Contour Interpolations Exercise.

of this kind is done with several types of instruments, the simplest of which is the hand level. Such work, however, while accurate, is not rapid and is therefore not suited to sketch mapping.

In sketch mapping the method followed is to determine

the **vertical angle** of one point above another, and, knowing this angle and the horizontal distance, the difference in elevation can be computed or obtained graphically. To measure the vertical angle, either a clinometer or a slope board

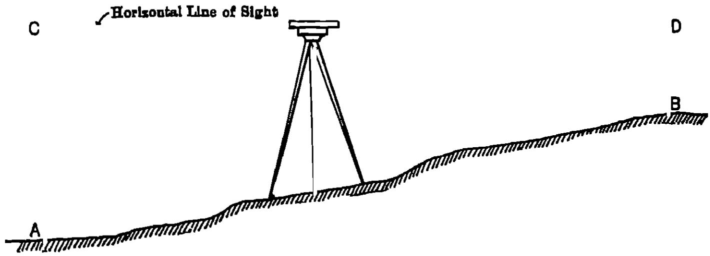


FIG. 65.—Spirit Leveling

is used. Several forms of clinometers have been devised by means of which the vertical angle can be quite accurately and rapidly measured, but the **slope board** is the simplest device available and though clumsy is quite as accurate as most clinometers. The slope board is shown as part of the

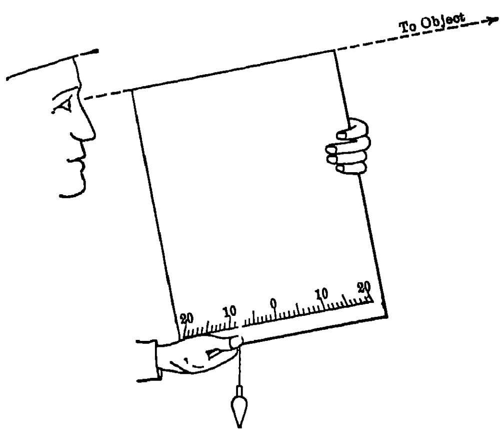


FIG 66—Method of Using Slope Board

sketch case equipment in Fig 55. It is also illustrated in Fig. 66, which shows the method of holding the board in the left hand while the plumb line is steadied by the right hand, the vertical angle being read on the scale at the lower edge of the board.

When using the slope board it is held at the level of the eye, which is about five feet above the ground. In order to make the line of sight parallel to the inclined distance and obtain the true vertical angle it is necessary to sight an equal distance above the point *B*. In Fig. 67 the observer at *A* sights at his assistant at *B* and the line of sight *FD* is parallel to the inclined distance *AB*, hence the angle *DFE* equals the vertical angle *BAC*. The distance, *DE*, which is obtained by using the former angle and the horizontal distance *AC*, equals the true difference in elevation, *BC*. It is frequently inconvenient and it is unnecessary to send an assistant to stand at the point *B* which is sighted to. Instead of sighting at the correct distance above the ground level at *B* the observer can sight at the ground and correct the distance of elevation

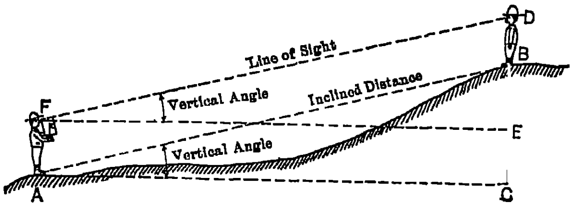


FIG 67 —Measurement of True Vertical Angle

so obtained by about five feet, thus allowing for the height of his eye above the ground. Note that this correction must be added to differences in elevation which are upward and subtracted from distances which are downward. In Fig. 68 the vertical angle measured by the slope board is not the true angle and the difference in elevation obtained by using it is *BD*, while the true difference in elevation is *BC* or equals *BD* plus the height of the observer's eye above the ground *DC*. In Fig. 69 where the sight is downward, the difference in elevation obtained by using the angle measured with the slope board is *DC* which must be corrected by subtracting the height *DA*, as the true difference in elevation equals *AC*.

In order to obtain the difference in elevation the horizontal distance is always necessary, as well as the vertical angle. This does not always require pacing the distance to

the object sighted. A point may be located, for example, by intersections, in which case the horizontal distance can be scaled from the map by using the reading scale on the alidade. Indeed the diagram, Fig. 70, described below, requires that

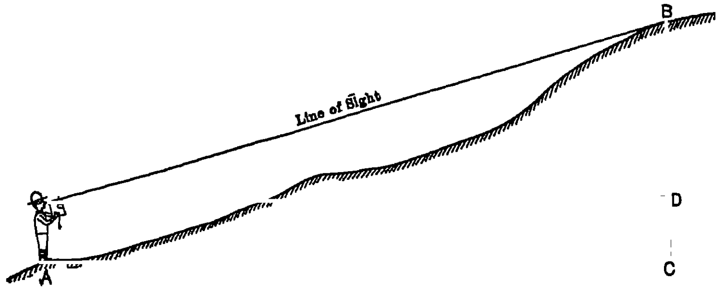


FIG. 68 —Correction of an Upward Sight.

the horizontal distance shall be in yards, and it is therefore necessary to scale from the map the horizontal distances used in determining the difference in elevation. Knowing the vertical angle and the horizontal distance the difference in

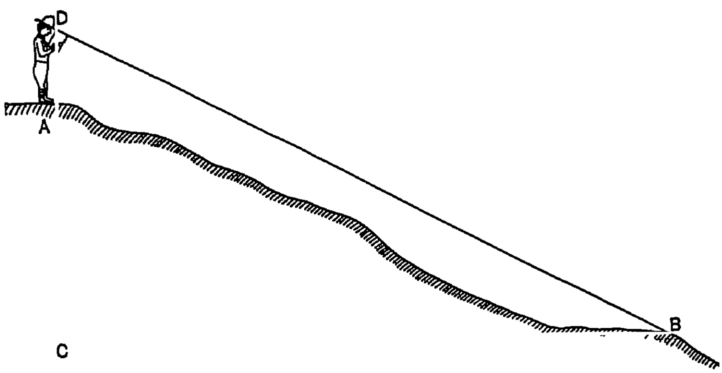


FIG 69 —Correction of a Downward Sight

elevation is found by solving the right-angle triangle *ABC* of Fig. 53 for the side *BC* That is, we may lay off the vertical angle *BAC* to scale and also the horizontal distance, and then scale off the height *BC*. Or we may solve this triangle by proper mathematical formulæ. A large amount of time and labor can be saved by using a **slope diagram** such as that

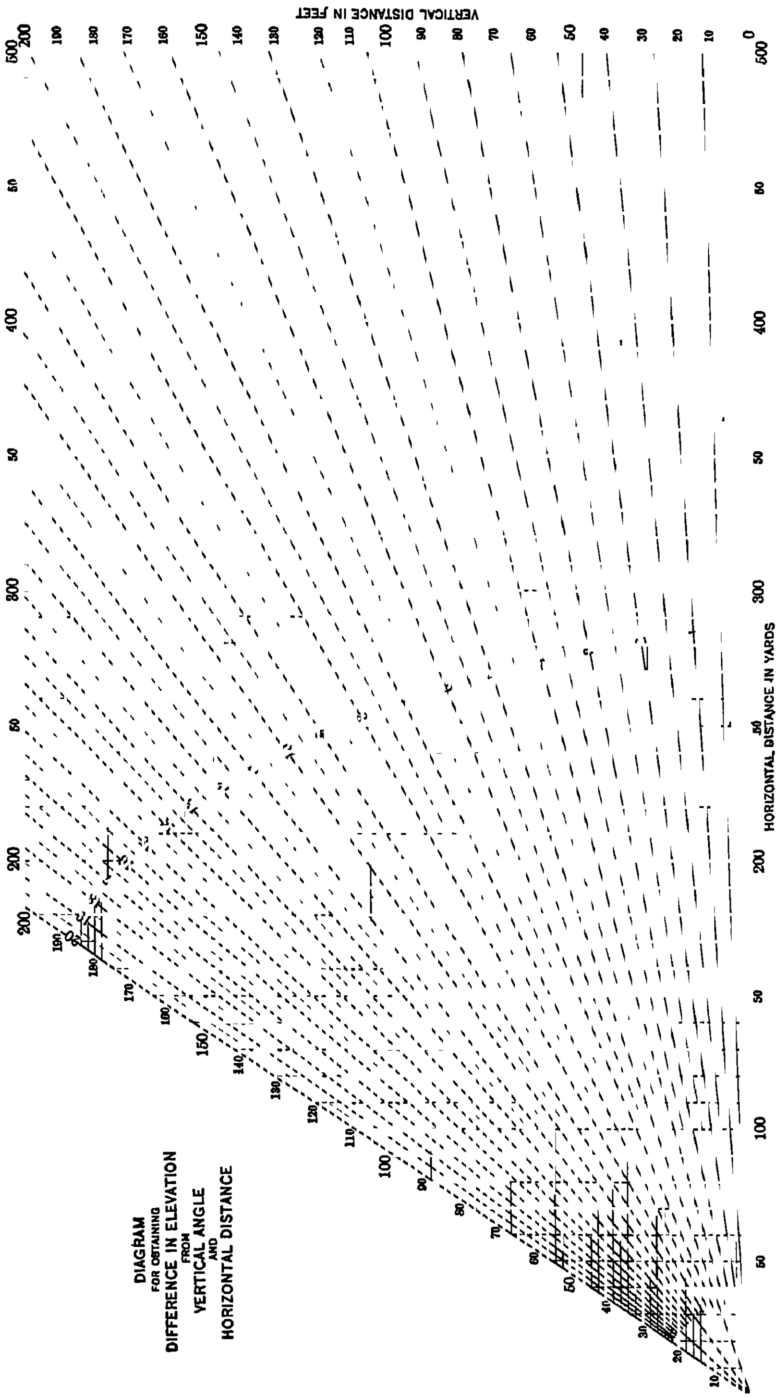


DIAGRAM
FOR OBTAINING
DIFFERENCE IN ELEVATION
FROM
VERTICAL ANGLE
AND
HORIZONTAL DISTANCE
VERTICAL DISTANCE IN FEET
HORIZONTAL DISTANCE IN YARDS

FIG. 70.

illustrated in Fig. 70, which consists simply of a drawing to scale showing a large number of vertical angles and horizontal distances which enable us to secure graphically the difference in elevation without making a separate drawing for each problem. If a horizontal distance, for example, is 500 yds., and the vertical angle is 3°, the difference in elevation may be read on the right-hand edge of the sheet as about 80 ft. If the distance had been 300 yds. the difference in elevation read in the same way would have been about 48 ft. Distances greater than 500 yds. can be handled by the same diagram by dividing the distance in two or more parts and adding together the vertical distances obtained for each part.

EXERCISE

Determine the elevation of the different set-up points in the closed traverse used as the exercise in connection with Art 24. Assume the elevation of the starting point as 100 or any other figure necessary to make all the elevations plus, that is, above datum. Determine the elevation of the points by using the slope board and the distance scaled from the map Continue this process completely around the traverse and distribute the final error in elevation in proportion to the length of the sides

Art. 29. Contour Mapping

The successive steps followed in securing contours have been dealt with in the last two articles. The student, however, will find considerable difficulty in putting the process into practice in the field. He must first of all learn to do the reverse of visualizing relief from the contours In other words he must learn to picture in his mind the proper contour forms for the different hills and valleys which he actually sees in the field and to sketch in these contours on his map This will require considerable practice, and some men will be far more proficient in doing this than others. One of the most important points in contouring work is to analyze the relief visible from any set-up and to decide upon a suitable scheme of controlling or critical points which will give adequate data for the actual work of interpolating and sketching in the contours themselves.

The contouring, of course, proceeds continuously with each

set-up of the instrument in just the same manner as the location of details. It is probably best to locate the details first and then obtain the location and the elevation of the controlling points on the map, finally sketching in the contours just before leaving the set-up. It is seldom indeed that anything but the roughest kind of contours can be drawn from any one set-up without actually moving over the ground and noting its conformation. For this reason the instrument man should call to the table his assistants who have been over the area and who can help him in the work of properly interpreting the relief by contours. It is desirable to use a colored pencil for the contours, as they otherwise may not show up properly or may be confused with other lines on the map. Where compactness and lightness of equipment is essential the additional slope board may be done away with and the sketch board itself used also as a slope board. The alidade may be used instead of a plumb bob and the slope scale and reduction diagram may be placed on opposite sides of the board.

In locating the contours from any one set-up it is always desirable, as noted above, to have in mind a certain definite scheme or method of attack. For this reason it is well to proceed as follows:

1. Having located the point of set-up and while securing the topographical details near this point by radiation or other methods, the instrument man should study the relief, noting the drainage and hill forms in order that he may have clearly in mind the points which he will adopt as controlling points for the contouring. Note in this connection that it will frequently happen that points located on the map to show topographical details may also be suitably located for contour points.

2. An assistant should use the slope board and by its means determine the elevation of the point of set-up, secure the vertical angles to various points already on the map which are to be used for contouring points, and compute their elevations. These elevations should be noted on the map by the mapper.

3. The mapper should then proceed to locate additional

contour points while his assistant at the same time determines their elevations by means of the slope board.

4. The contours are now interpolated exactly as described in Art. 27 and are drawn-in in the field, where the ground is in front of the mapper. Note particularly that contours which pass out of view or are in back of hills cannot be drawn without proper observations, and no contours should be guessed at which are out of sight unless special note is made of the fact that such portions are simply probable contours and not accurately determined. This may be done by showing such contours with a dotted instead of a full line.

EXERCISES

1. (*a*) Place a piece of tracing paper over the upper right-hand corner (say six inch square) of the Hunterstown sheet, which will be found in the back cover, and mark on this paper the drainage lines and what you believe to be the necessary controlling points to make a contour map of this area, (*b*) estimate the elevations of these points from the contours, (*c*) remove the map and interpolate contours from these selected points as described in Art 27; (*d*) compare the contours so drawn with the original map. In this way obtain some practice in the selection of controlling points for different forms of relief
2. Contour carefully a small area, using the sketch and slope boards and showing contours alone.
3. Complete the map used as an exercise in previous articles by filling in the contours of the entire area.

PART III

LANDSCAPE SKETCHING

INTRODUCTION

Landscape, or Panoramic **Sketching,** is used to a large extent in military work in making conventionalized pictures. particularly from artillery positions. These sketches show the enemy positions with approximate ranges and with descriptions of important targets. They are sometimes made by reconnaissance parties or again are made as a record of an enemy position for the information of the next detachment, or relief, occupying the position from which the sketch was made.

A sketch of this kind is simply a conventionalized, outline, perspective drawing showing the view from any position, and with additional data in reference to the direction and range of important targets, such as points of special enemy activity, etc. The student should understand that a landscape sketch is not an artistic effort The work must often be done very rapidly and many sketches show only rough crest lines with indications of intervening ridges and hills. Only outlines are shown—the minute and smaller details being left out—and it is preferable to think of a landscape sketch simply as a map in a vertical, instead of a horizontal plane. It is drawn to scale just like other maps.

In order to make a sketch **four steps** are necessary. 1, A system of delineations, or special conventional signs suitable for this work, must be agreed upon; 2, the student must have some knowledge of perspective, as this is essential in putting these signs together so as to form even a rough landscape sketch; 3, inasmuch as the sketch is to be drawn

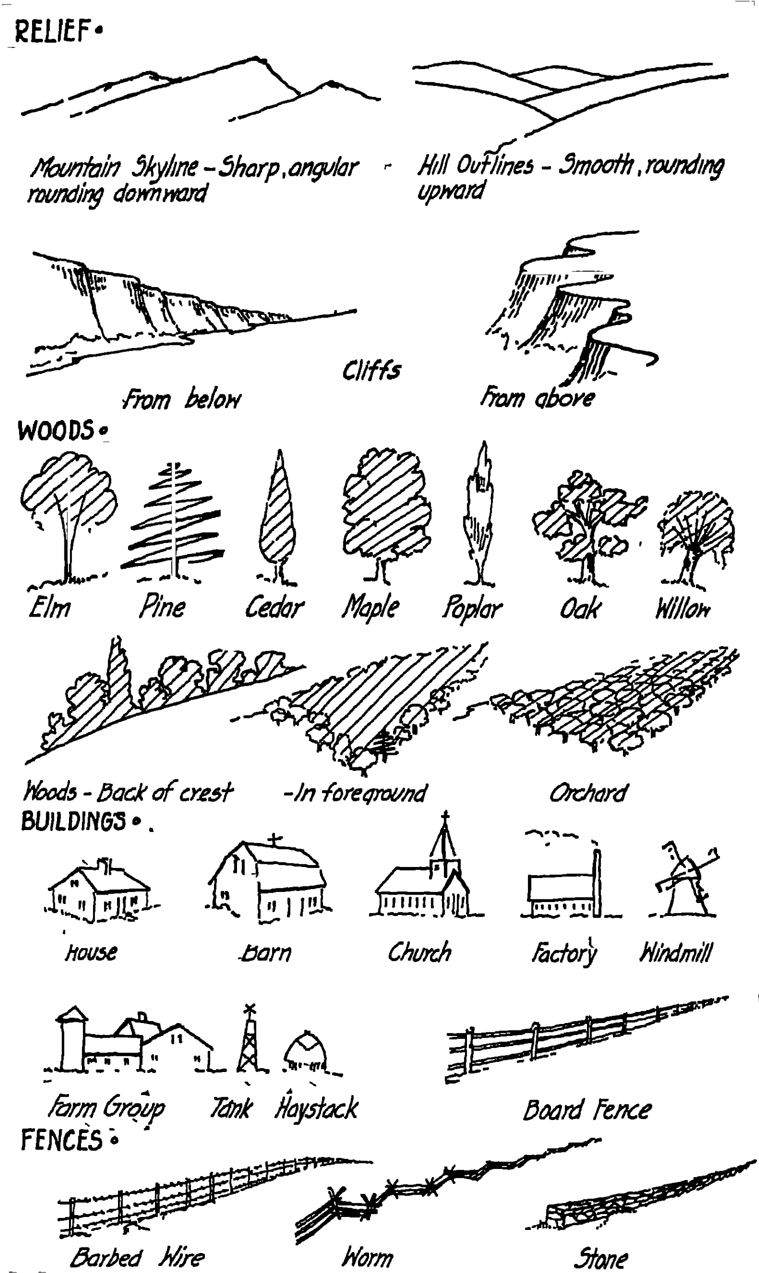


FIG 71.—Delineations

to scale and points must be shown in their proper relative position, particularly as regards direction, the sketcher must be familiar with the scale used; and 4, he must know how to locate on his sketch the main features of the landscape so as to secure guide points which will control the freehand work of sketching in the other features and give accuracy to the sketch. These various steps will be discussed in order.

Art. 30. Delineations and Perspective

As stated above **delineations** are simply the conventional signs of landscape sketching. They are not nearly as mechanical, neither have they been as thoroughly standardized or conventionalized as those used for "horizontal" maps, hence there is considerable opportunity for the sketcher to add to the neatness and appearance of his sketch if he possesses special ability in freehand work. On the other hand men with this ability frequently go to the extreme and try to show too much, while the novice goes ahead in a much cruder way and finally produces, not a "beautiful" sketch, but a simple outline drawing which is just as, if not more, useful.

The main thing to work for in practicing delineations is *a simple outline* which will be *suggestive of the object represented* Figs. 71 and 72 show some simple forms which should be copied, not with the idea that they will cover all possible objects, but that they will suggest similar simple outline treatment for other objects

In order that the sketch may give a correct impression of the landscape represented it is necessary for the sketcher to give such effect of **distance** and perspective as his skill permits The former effect is secured by drawing the delinations of the more distant objects smaller in size, just as these objects actually appear, with a fine light line and increasing the weight of the line used for objects nearer the observer. The rough outlines of one or two objects in the foreground frequently assists in securing the effect, but such objects should be sparingly shown, as they are of no importance except in this connection and in assisting to identify the point from which the sketch was made

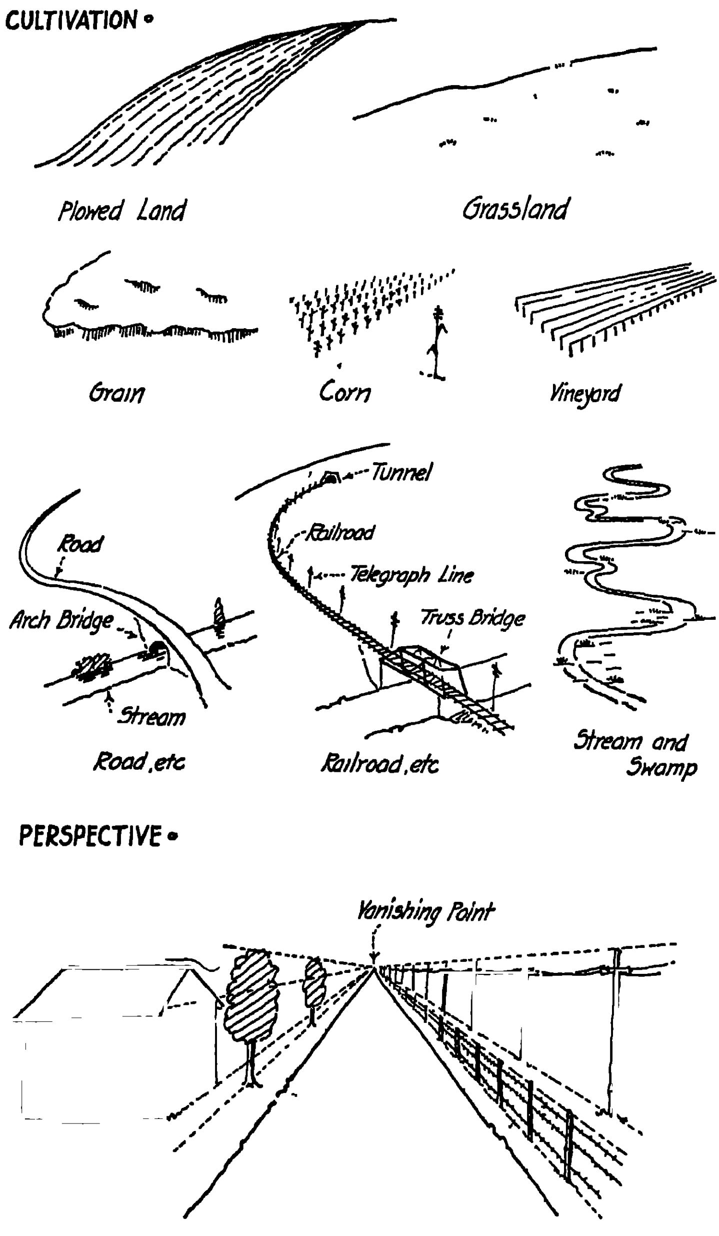


FIG. 72 —Delineations and Perspective.

In connection with **perspective** it is particularly necessary that the student should understand the simple principles illustrated in Figs. 72 and 73. All parallel lines, such as the sides of roads, for example, or imaginary lines, such as those indicated in the sketch in the lower part of Fig. 72, appear to gradually converge as they become more distant from the observer and finally seem to meet at a point known as the vanishing point. Also note in this simple perspective how the

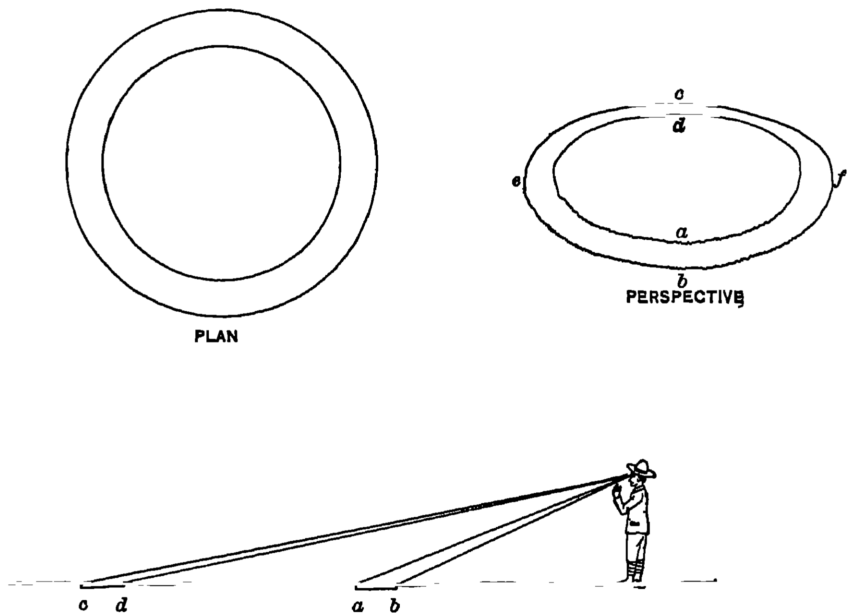


Fig 73 —Perspective of a Circular Path.

spacing of the poles of the telegraph line becomes smaller and smaller the further they are away. Now note the delineations shown above for fences, roads, etc., and how this same perspective effect is secured.

Another feature in perspective is shown in Fig. 73. Imagine a circular driveway or track. The perspective appears wider in the foreground *ab* than at the back *cd* as shown in the sketch, due to the fact that the angle subtended at the eye by the two edges of the roadway is greater for the nearer portion. Also note that the sides at *e* and *f* appear their

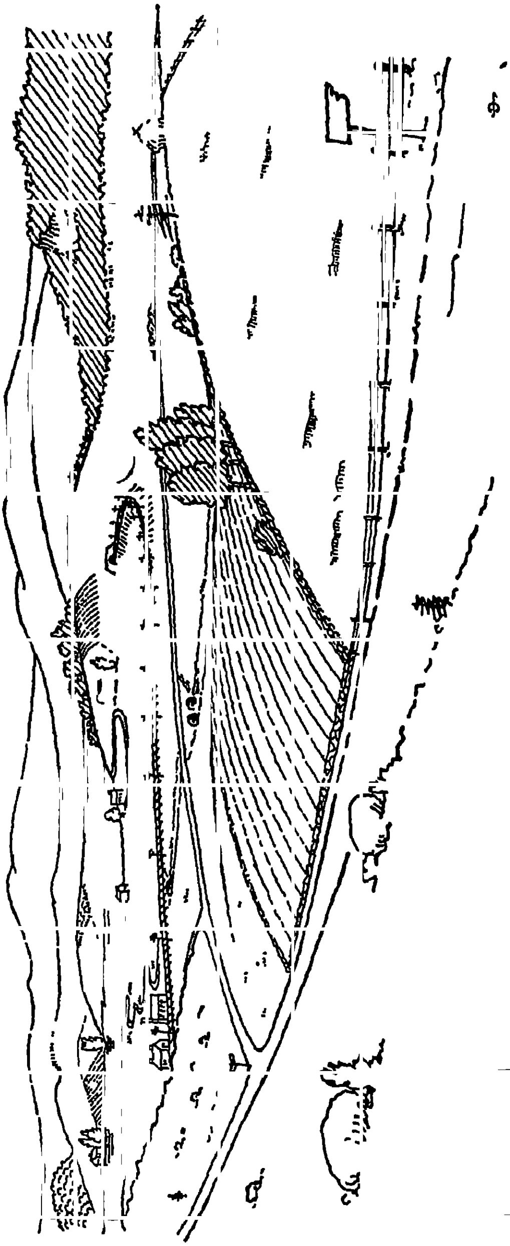


FIG 74 —Landscape Sketch

full width. Applying these same principles to the case of a winding stream we understand how the stream shown in Fig. 72 is drawn. Fig. 74 shows a landscape sketch and illustrates how various delineations are combined to produce a clear drawing when due allowance is made for perspective effect. Note the varying size of the delineations and also the variation in the thickness of the line used which, together with the rough indication of foreground objects, gives the effect of distance.

EXERCISES

1. Copy Fig. 71.
2. Draw the required number of vertical lines one inch apart and horizontal lines at half this distance and enlarge Fig 74 by the same process followed in the method of squares, Art. 21.

Art. 31. The Sketching Screen

The sketching screen is a device which is never used by the experienced sketcher but is of value in assisting the

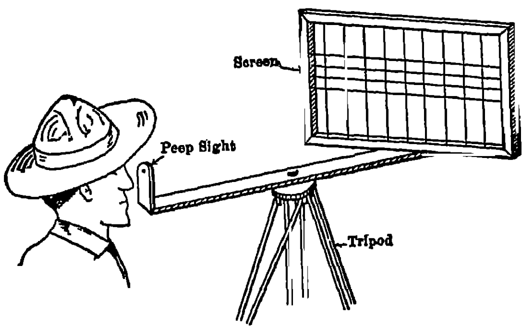


Fig 75 —The Sketching Screen.

beginner. It consists of a rectangular frame, as shown in Fig. 75, fastened to one end of a horizontal bar, the entire apparatus being mounted on a tripod. A series of vertical and horizontal cords divide the opening in the frame into rectangles. When this apparatus is set up, as illustrated in the figure, and the observer looks through the screen the vertical and horizontal cords will divide the portion of the landscape, viewed through the frame, into a series of rectangles. The extent of country covered by each rectangle will, of course,

vary with the distance of the observer's eye from the scre For this reason a peep sight is placed in a fixed position the other end of the bar and opposite the center of the scre

In using the sketching screen a sheet of paper is ru with vertical and horizontal lines just like the lines in t screen. The process of making a sketch from the landsca thus reduces practically to a problem of transferring t lines of the landscape to the paper, rectangle by rectang by a similar process to that used in the enlargement of m by squares described in Art. 21. Thus seen through t screen a house is noted as being in the second rectangle fr the left and third from the top and it is then drawn in proper position in this rectangle on the ruled paper. It of course unnecessary to transfer every detail from the la scape to the pad in this way. The main points in the la scape are located with the screen and the remaining det are drawn by eye, using these points as guides.

The process of making a landscape sketch with the of the sketching screen is very simple and easily understo The difficult part of the work is not in drawing delineati for simple isolated objects such as houses, trees, etc., in th proper position on the paper, but in "seeing" the lines of t landscape which are needed to represent the ground fo properly in the drawing. It is best to start by locating four or five of the most prominent objects as main gui points and then drawing the sky line and working forwa drawing only the ridge lines first and leaving out all trees a woods. The roads should next be drawn, then the fenc etc. Bear in mind that the effect of distance and form the relief in the sketch is obtained almost entirely by dra ing these objects curving over the hills and valleys as th appear in nature, with careful attention to their perspecti Be careful also to take full advantage of the weight of li used to bring out the effect of distance.

The next step in finishing the sketch should be the woo which must be drawn with simple outline. Distant woo can be shown by a single line indicating roughly the o line of the tree tops; woods nearer the observer are indica by rough outlines of the most prominent trees. Woods sho

never be drawn so as to cover up other details that can be clearly seen by the observer.

In finishing a sketch of this kind remember that, while it is called a sketch, this does not mean that the lines of the drawing can be made carelessly or too freely. As already stated such a sketch is essentially a map drawn in a vertical plane, and the same care must be used in drawing the lines of this sketch as is exercised in drawing the usual conventional signs or in doing freehand lettering. Use a slow uniform motion of the pencil which will give a sharp, definite line and omit all shading or other lines which have no definite purpose or indication in the sketch.

EXERCISES

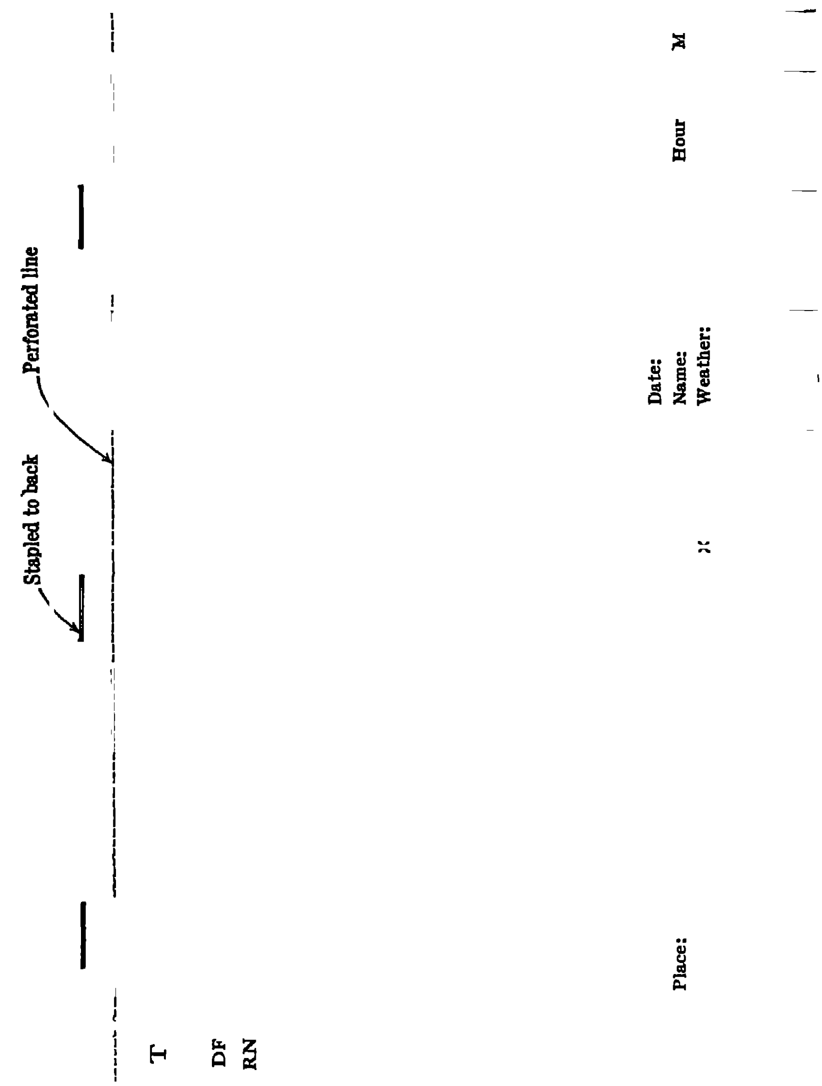
1. As a practice in analyzing a landscape, and choosing simple outlines to represent its main features, select several photographs or magazine pictures of simple landscapes, place a piece of tracing paper over each of them in turn and trace the outlines necessary to show the main features
2. Construct a sketching screen as described in Appendix 2 and practice with this apparatus in the field Select simple views from hill-tops or positions where quite an extensive outlook can be had. Detailed sketches of objects very close to the observer are not desirable In artillery work the important part of a sketch is usually a target a mile or more distant from the observer In machine-gun work the middle distance is important The foreground is of value only in infantry work, where the ground to the objective must be traversed by the troops and the best route as regards going and cover is to be selected.

Art. 32. The Sketch Pad

The sketching screen, while accurate and very useful to the beginner, is clumsy and cannot be easily carried in the field. For this reason it is not used by the experienced sketcher. The horizontal and vertical lines on the sketch pad, with the aid of a piece of string, can be made to serve the same purpose.

Fig. 76 shows a page of a sketch pad in reduced size. The actual pad consists of a stiff cardboard back, 6½ by 9 inches in size, to which a number of the printed forms shown in the figure are fastened. The vertical lines on these forms are one inch apart and the horizontal lines one-half inch. The lettering, etc., on the forms is described in Art. 33.

A piece of string is fastened to the bottom of the pad and a knot is put in the strıng at twenty inches from the pad. In using the pad the end of the string is held in the teeth and



the pad in the left hand. Thus the string fixes the distance from the observer's eye to the pad, just as the peep sight does with the sketching screen, and the lines on the pad itself

take the place of the frame and strings of the screen. The pad, not being transparent, has to be used in a slightly different manner than the screen. That is, we locate points of the landscape in their proper position on the pad not by sighting through it but by noting their positions along the top and side edges of the pad. The procedure is as follows:

1. The sketcher selects some prominent point on the landscape as a "reference point" and locates this point at the intersection of one of the vertical with one of the horizontal lines of the pad.

2. Other prominent, or guide points, for the sketch are first located on or between the proper vertical lines, to the right or left of the reference point, by using the top edge of the pad as a scale. Thus with the pad held vertically, twenty inches from the eye, and with the selected *vertical* line directly under the reference point on the landscape, we note, by sighting along the upper edge of the pad, that some prominent object is two and one-half vertical spaces to the right of the reference point. Now holding the proper *horizontal* line even with the reference point and sighting down the vertical edge of the pad we see that this same object is, say, one horizontal space below the level of the reference point. The intersection of two lines, the first a vertical line two and one-half spaces to the right of the reference vertical and the other the horizontal line below the reference point, determines the location of the object on the pad.

3. Having located in this manner on the pad a number of the main points of the landscape the observer proceeds to sketch in the landscape as previously described.

In many cases it is desirable, in order to get more space and hence a clearer sketch, to exaggerate the vertical scale of the drawing. For example we may note the number of horizontal spaces an object is above or below the reference point and then double this value when plotting its location on the pad. This procedure is similar to that followed in making profiles. The effect on the sketch is to make it appear that the observer had made the sketch from a much higher elevation than he actually occupied.

EXERCISE

Following the hints given in regard to the selection of landscapes in Art. 31, a number of sketches should be made, using only the sketch pad.

Art. 33. Descriptions and the Mil Scale

Fig. 77 shows a landscape sketch with the complete data as regards location, etc., filled in. Thus the arrow, drawn from the cross mark at the center of the bottom of the pad shows the direction of north. The view illustrated in the figure therefore shows the country in a northwest direction. Place, date and name need no explanation. Weather and time are sometimes important on account of the clearness and extent of the view under different atmospheric conditions and lighting.

The lettering at the upper left-hand edge of the pad is used in describing various important points of the sketch. *T* stands for **target** and in the horizontal space provided a brief description of an important target such as "red house," "machine gun emplacement," etc, can be given. *RN* stands for **range** or the distance in yards from the observer to the object. This may be scaled from a map, estimated, or determined in some other manner The abbreviation *DF* is for **deflection,** or the angle to the right or left of the reference point, which point is shown by an arrow and marked zero.

In measuring deflections, or angles, in military work it is the practice both in the United States and in France to use a special unit instead of the usual degrees, minutes and seconds. The scheme used is known as the **Mil System** or Scale and all instruments used, such as angle measuring instruments, protractors, etc., are divided in this scale. A mil may be defined as the angle formed at a point by two lines, each one thousand units long, and one unit apart at their far ends. Thus the angle between objects one yard apart and distant one thousand yards from the observer is one mil A mil represents an angle of about $3\frac{1}{2}'$, but being a ratio (the ratio of the base of a triangle to its altitude) a number of calculations are simplified,* or can be solved approx-

*See Danford and Moretti, "Notes on Training Field Artillery Details," Yale Press

imately with great rapidity. The system is also used in directing rifle fire *

The angular distance in mils of two points at different

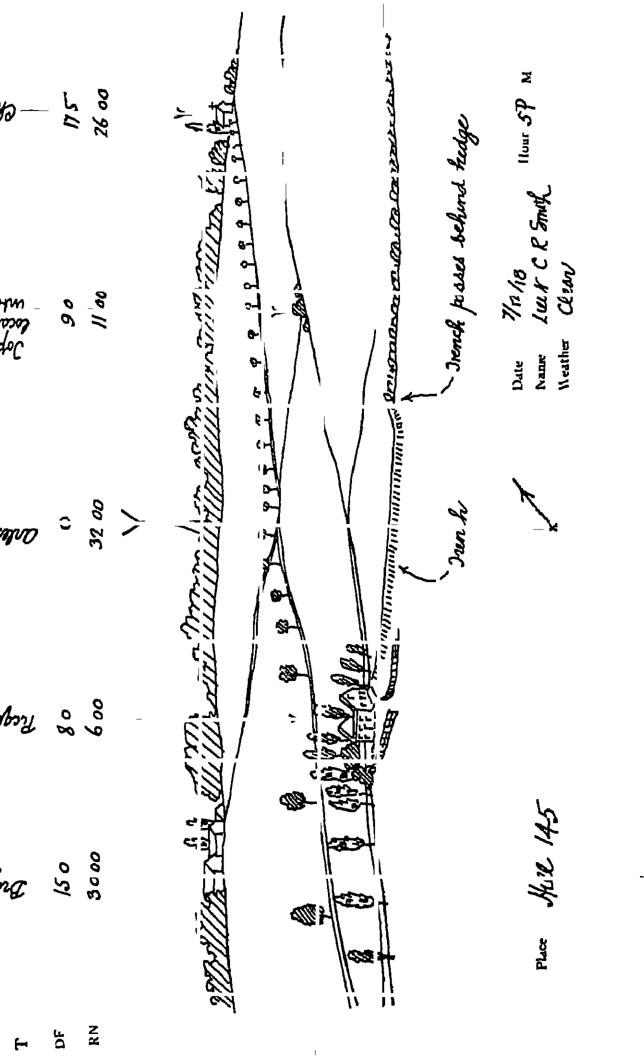


FIG 77—Complete Landscape Sketch

distances can be easily found For example the angle between two points ten feet apart and one thousand feet distant is

* See Moss, "Manual of Military Training."

ten mils. If these points had been only 500 feet distant the angle would have been twenty mils, because a ratio of 10 in 500 corresponds to 20 in 1000. Thus the vertical lines of the sketching screen, being one inch apart and twenty inches from the eye, determine an angle of fifty mils (1 in 20 or 50 in 1000). The same relation is true for the lines of the sketch pad, and the scale of our landscape sketches may therefore be said to be fifty mils to an inch.

EXERCISES

1. Make a landscape sketch of a section of country of which a map is available. Give complete data on sketch including description of important points and ranges scaled from the map
2. A train is ten cars long and the average length of a freight car is forty feet. The angle at the observer is measured and found to be eighty mils. What is the range?

NOTE

Topographic Maps of the World

This publication formerly contained, as an appendix, a descriptive list of the principal topographic maps of the different countries of the world Such a descriptive list requires, of course, more or less continuous revision, and, since the original publication of this work, a new list has been prepared by Mr. Walter Thiele, and published (1938, mimeograph, 350 pages) by the American Library Association, Chicago, under the title "Official Map Publications." It is understood that data on such maps are also available through the Geographical Bureau of the Department of State, Washington, D. C. Accordingly, the former appendix material is omitted in this reprinting.

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